1981

A High School Curriculum in Marine Environmental Issues: "The Sea - Use and Abuse" Part II

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A HIGH SCHOOL CURRICULUM

IN

MARINE ENVIRONMENTAL ISSUES

"THE SEA - USE AND ABUSE"

BY

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REQUIREMENTS FOR THE DEGREE OF

MASTER OF MARINE AFFAIRS

PART II

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STUDY QUESTIONS

ROLES FOR NEW ENGLAND PORTS

The report on New England Ports prepared for the New England River Basins Committion dated November 1980 should be studied and read. There are questions based on this information which should give you some understanding of the complex issues and decisions that are facing urban planners and citizens relative to New England ports in the 1980's. Give special attention to the graphs.

Briefly answer the following questions:

1. What impacts do adjacent ports have on Boston's ability to attract cargo? Give specific examples.

2. Why is New England cargo often diverted to New York and/or New Jersey? How does that affect New England?

3. What is considered the greatest market potential for the New England ports?

4. What is a "load center" port? Why is that favored at Boston? What are some of the prerequisites?

5. Note the areas that are delegated as expansion areas for Massport. Why was this plan adopted?

6. What would be the impact of an additional major port in New England?

7. Which cities could possible be so developed to adopt such a plan? Explain some of the impacts.

8. Why is a "substantial portion" of the container traffic in Boston transshipped to New York and Haliifax from/for shipment with foreign countries? Do you think this might be changed? How?

9. How does the "feeder system" operate now in New England? Discuss the potential changes that it could undergo and the results.

10. Discuss the economic benefits to be derived from neo/bulk or bulk trade and from general cargo.

11. What are some of the pros and cons of port specialization for specific cargoes in the New England area?

Study Questions: Roles for New England Ports

12. Which types of transportation is favored for general cargoes in the New York- New England areas? Give specific examples.

13. Under what conditions is barge transport more economical? What are some of the contingencies to be evaluated:

    a. For truck service

    b. For barge service

    c. For back-haul service to New England

14. What impacts on New England will the resurgence of coal as an energy source have on:

    a. Waterborne transportation

    b. Channel depths

    c. Two major users of coal in New England

    d. Brayton Point

    e. Atlantic Terminal, Searsport to Thomaston, Maine plant

15. What is necessary in order for a common user facility to handle large quantities of coal?

16. Explain some of the conflicts between water dependent and water enhanced industrial, or commercial activities.

17. In which category would you place port operations? Why?

18. The utilization of prime waterfront lands is a major and complex concern of the 1980's. List what you consider to be some significant factors that will have to be analyzed, evaluated, and determined relative to land use. Give specific areas and problems if possible.

Study Questions: Roles for New England Ports

The following questions are based on the graphs that are listed as "Exhibit". Study each carefully, and complete the following questions:

Exhibit 3

1. Contrast New England and other US ports in reference to imports and exports. Note the specific foreign area relative to the data.

2. Which area of the world trade market does New England conduct most of its import trade? Export trade? Least trade?

3. Which section of the USA has the greatest percentage of general cargo distribution? Whith which area of the world?

Exhibits 4 - 5

1. Carefully study both exhibits 4 and 5 and answer the following briefly:

1. Which is greater -- New England import or export?

2. Explain some reasons that account for this?

3. What is the major import?

4. What is the major export?

5. List one manufacture in the Lexington area (Waltham, Burlington, Woburn may also be contacted.)

   a. Explain the manufactured product.

   b. What amount is exported throught the Port of Boston?

   c. How is this transported -- rail - truck - sea?

   d. If possible show statistics for the past few (4-5) years for that particular company.

Study Questions: Roles for New England Ports

The following questions are based on the graphs that are listed as "Exhibit". Study each catefully, and complete the following questions.

Exhibit 6

1. Which years and amounts illustrate the greatest import years for all types of vessels?

2. Which years have the lowest? What do you think accounts for this?

3. What years were the imports/exports percentages of New England ports greater/lesser than other North Atlantic ports?

Exhibit 7

1. Comment on the changes that have taken place in the routing of New England general cargo trade both in imports and exports. How does this compare with New York, all other US ports, and with Canada?

2. For extra credit: determine how much cargo is transshipped through other US ports. Choose one large port on either the East, West, or Gulf coasts.

3. What conclusions can you make from the data on this graph. What changes would you like? Why?

Exhibit 8

1. Which years show the greatest and the least amounts of imports and exports via the Port of Boston?

2. Contrast the overall imports vs. exports for the Port of Boston.

Seaports

Seaports are links of vital importance in the transportation chain and it is, therefore, essential that ports are properly planned to meet all foreseeable demands. The economics of port investments ought to be based on a short enough lifetime of the installations to allow ongoing adaptation of facilities to meet the constant changes to which the modern transport industry is subject.

Seaports are the points where carriers of goods switch from one mode to another. All seaborne transportation today is accepted as only one link in a more or less integrated through transport chain, whether the cargo be general, unitised, dry bulk or petroleum.

The present inadequcies encountered in those port installations designed and built in the 1950's stem from the fact that they were too closely matched to the ships of that time. The necessity of integrating sea and land transportation was only realised later in the 1960's. Intercontinental trade should be regarded as flows of goods which are trans-shipped from one mode of transport to another at seaports with a minimum of delay. Congestion at seaports, whether on the landward or seaward side, costs large sums of money to resolve. It usually takes a heavy commitment of men and machinery to sort out a traffic jam on the landward side, and causes substantial losses, both material and financial, to cargo owners. If the jam occurs on the seaward side there are heavy demurrage charges to pay for the time the ships lie idle. One notable example was the disastrous congestion that occurred in Nigerian ports during 1974, 1975 and 1976 as a result of Nigeria's huge purchases of cement. 500 ships had to wait outside Nigerian ports for anything from a few months up to a whole year to discharge their cargoes, the total cost running into billions (10^9) of dollars.

An efficient, well adjusted port handles a reasonably steady volume of traffic and, thus, enjoys optimum economic conditions. Efficient port operation is a national concern. Just as the construction of roads, railways and airports needs to be planned on a broad and far-reaching basis of integrated transport policy, so does that of seaports.

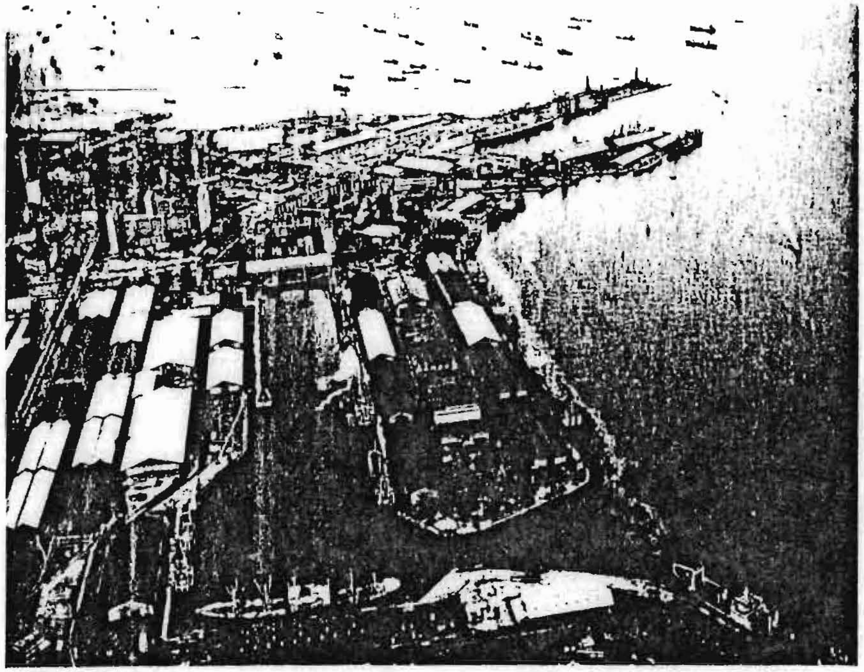
SOURCE: SHIPPING-HOW IT WORKS. THORSTEN RINMAN AND RIGMOR LINDEN. GOTHENGERG, SWEDEN. 1978.

Integrated transport planning will open up new opportunities for the economic expansion of those great continents which remain underdeveloped today. Sea transportation, as such, is now so cheap that its cost can practically be disregarded in international trade. What costs money is the business of berthing the ship in the dock, transporting the goods overland to the quay, and loading them aboard the ship. It is the handling stages that are expensive in practically all transport operations. Only when the seaports of the great underdeveloped continents become efficient "pumping stations" between the seaward side and well developed networks of roads and railways reaching far into the hinterlands — the conditions needed for a high throughput — will the economic development of those continents be enabled to gather momentum.

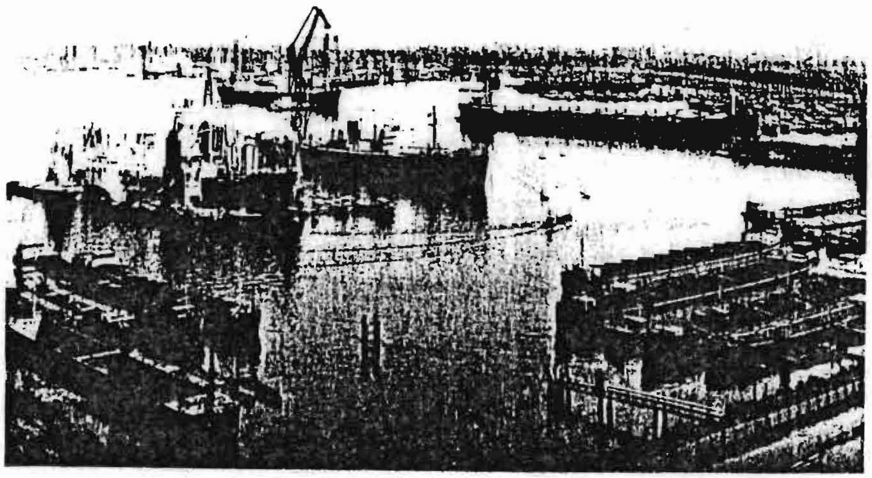
As the 1970's draw to a close, there is no sign on the seaward side of any transition to new and untried techniques. Here the methods, the economics and the efficiency already exist: it is in the ports and in the overland transport systems that modernisation must come.

As an example, suppose a country such as Japan wants to import large quantities of steaming coal from, say, Australia. There are no economic obstacles to this today so far as ocean transport is concerned, nor does the loading or discharging of "energy coal" present any great problems. The major economic obstacle lies within the overland transportation side because rail transport of steaming coal is uneconomical. With a different, integrated system, however, the coal could be moved economically. One conceivable solution is to link one or two large coalmines to a central seaport by pipelines. The coal could then be piped to the sea in slurry form and pumped straight aboard ship. After being transported by sea to Japan the coal, still in slurry form, could be discharged and conveyed by pipeline to coal-fired power stations, gasworks, etc. This proposal exemplifies the overall aim of transportation development: to move large volumes in a steady flow.

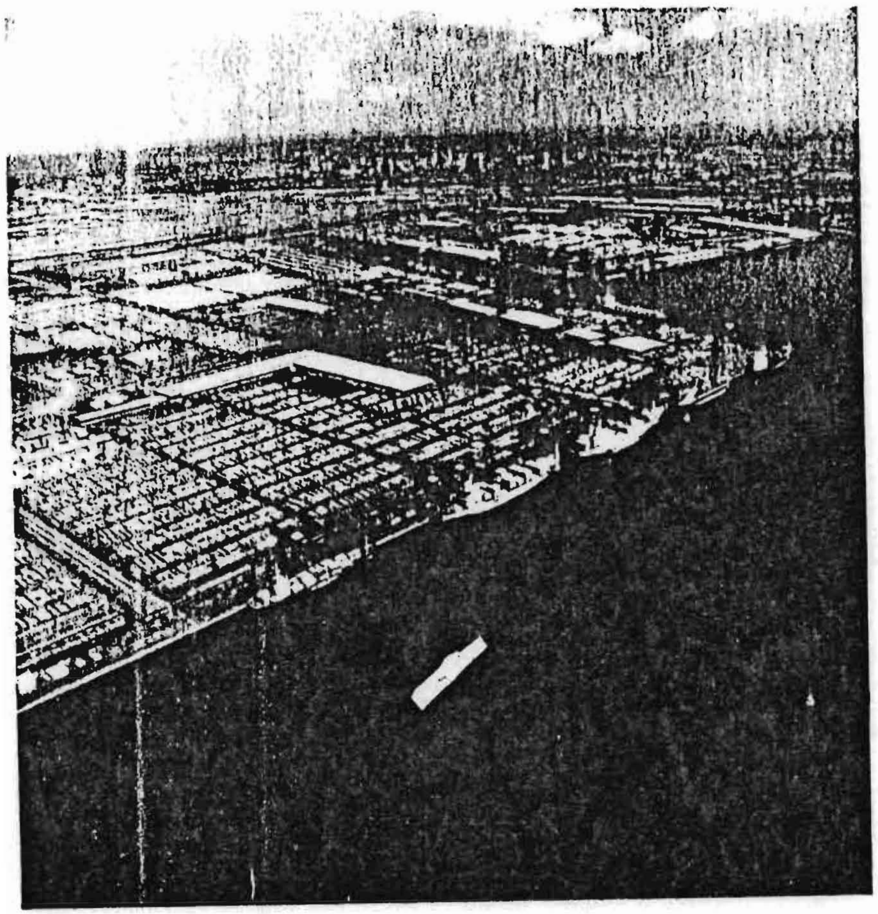
A container ship of 30 000 tons d.w. — including cargo, containers, hull and equipment — may represent a total value of perhaps US $ 200 million, so it is patently desirable to ensure that the ship operates efficiently in port as well as at sea. Up to two-thirds of those 200 million dollars are the value of the cargo which, allowing 2 containers per vehicle, will fill one thousand highway juggernauts! Liquid cargoes are transported overland by pipeline wherever possible, because the load of oil carried by a 400 000 ton tanker would take a train 250 kilometres (160 miles) long to haul away! Much congestion on road and rail is avoided by sea transport.



One of the container terminals in Singapore and part of the roads where usually hundreds of ships are anchored.



Waal-haven — Port of Rotterdam



Port Elizabeth one of the container terminals in the New York area

All these facts are well known today for transport economists and planners are well aware of the inter-relationships that exist. It is a challenge to the industrialized world to help the developing countries plan, finance and build efficient, cost-saving transport systems in which shipping has its natural part to play. This, perhaps, is the most valuable form of aid the industrialised part of the world can give: to provide the necessary knowhow and finance for the construction of top-grade transportation systems in the developing regions. This ought to be the dream of planners and engineers, for they would often be working in virgin territory from the point of view of transport technology. Such aid would, moreover, offer economic benefits to all through the potential expansion of trade arising from drastic reductions in overall transport costs.

In an earlier chapter of this book(Seaborne WorldTrade), the expansive forces in sea transport that will be generated by the economic development of the Third World were described. It was also explained how the expansion of the industrialised world over the past century would not have been possible without the enormous advances that took place in the technology and economics of sea transport. This expansion has already taken place at sea and on land in the industrialised regions of the world — its extension to the great underdeveloped continents of the world is a challenge to all mankind.

How a seaport works

A seaport may be State-owned, municipally-owned or privately-owned; it may be designed to handle a single commodity such as oil, ore, coal, cars or fruit, etc., or general cargoes of raw materials and manufactured goods in the import and export trades. In most cases, however, ports offer facilities for general goods of all descriptions. There are small ports which serve, maybe, a single factory or a fairly small hinterland while on the other hand there are giant ports like Rotterdam and Singapore which are the entrepots for vast regions.

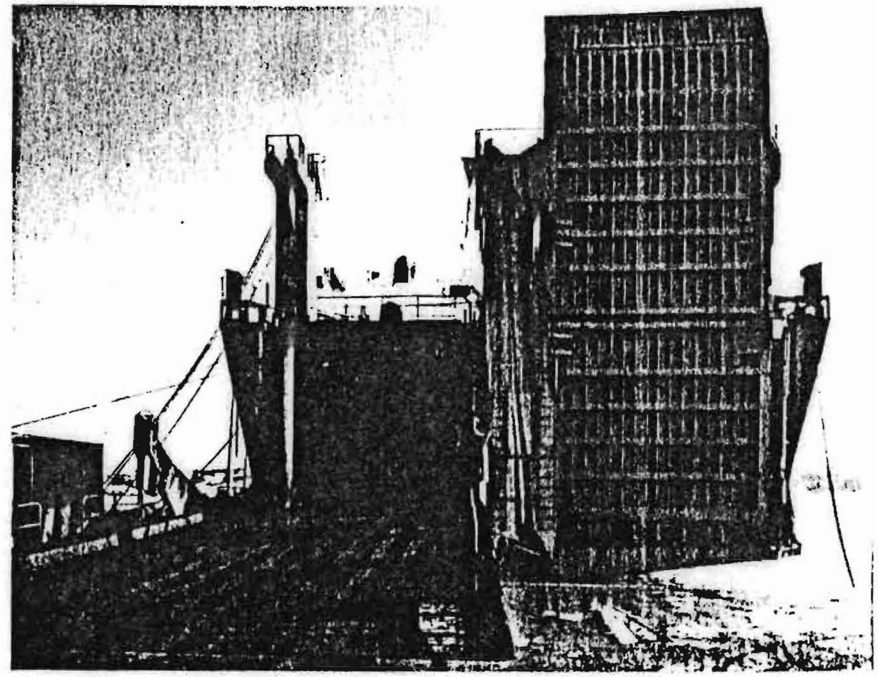
The hinterlands of seaports vary in character. For a port located at a rivermouth in an underdeveloped continent, the hinterland may be long and narrow. In other cases the hinterland may itself consist of sea — Singapore is a good example. Singapore is, of course, a small island off the coast of Southeast Asia and has two million inhabitants. 65 million tons of goods a year pass through its seaport, mainly in transit to and from Southeast Asia — a region which equals the USA in area and population and which has recorded the world's fastest economic growth rate during the second half of the 1970's. This means that Singapore has the same cargo through-put as New York.

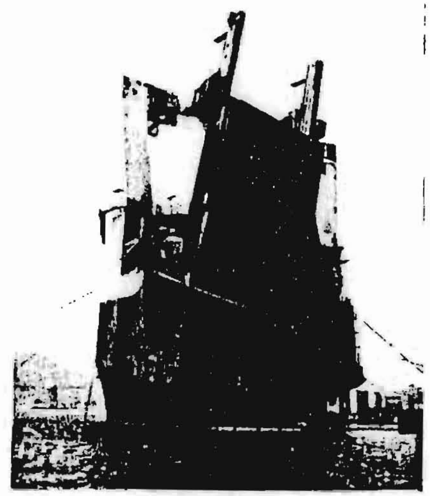
The hinterland of Rotterdam is of a different kind. Rotterdam, with an annual cargo through-put of almost 300 million tons is the largest seaport in the world. Its hinterland is served by a mighty and far-reaching network of rivers and canals carrying inland watercraft; by seaborne traffic fanning out in all directions to France in the south through the North Sea and the Baltic to Russia in the north; and by a spider's web of pipelines, railways and highways.

Many seaports — perhaps most — are subsidised in one way or another. The innate competitive strength of a seaport is reflected in the degree to which it depends on subsidies. To the competitive factors already mentioned, such as the nature and accessibility of traffic to the hinterland, must be added other factors such as harbour dues, cargo handling costs and turnaround times. The strikes that afflict US ports every few years naturally leave their mark on freight rates charged by the liner services that call at those ports, while the reputation of Rotterdam as an almost strike-free port has a beneficial effect on freight rates.

There are ports around the North Sea, similar in size and facilities, where due to the operation of various competitive factors the level of harbour dues shows such divergence that a 7 000 tonner may have to pay only US $1 000 in one port but US $10 000 in another. It costs about US $50 000 to load a 300 000 ton oil tanker in the Arabian Gulf, whereas the cost of discharging the oil in Rotterdam is about US $150 000. The corresponding figure in Gothenburg, for example, is about US $260 000.

Different types of traffic may also pay different dues, usually because the port or government concerned wishes to attract or protect a particular type of traffic. Of the figure just mentioned for a 300 000 tonner calling at the port of Gothenburg to discharge cargo, nearly US $220 000 consists of charges levied by the Government of Sweden. If however a 20 000 ton container ship calls at the same port to discharge 1 000 tons, the Government charges only US $2 000. The reason for this discrepancy is that the oil traffic to Sweden can bear a stiff Government levy on direct calls at Swedish ports while direct liner traffic cannot bear more than nominal charges because of the threat of competition from Hamburg and Rotterdam.





Examples of ro/ro ramps designed by Navire Cargo Gear.
Above: Double slewing ramp arrangement aboard "Emirates Express".
Left: Angled jumbo ramp with a load capacity of 600 tons fitted aboard the ro/ro carrier "Boogabilla".

Approximate time spent in port and at sea by ships of different types

Type of ship	% of time in port	% of time at sea
Container ship	25	75
General cargo carrier	60	40
Tanker	5	95
Ore carrier	10	90
Grain carrier	40	60
Coaster	35	65

When a cargo liner approaches a port with a cargo from some foreign continent, shipping agents will already have been busy for a week or two getting exporters' goods to the port by road and rail after having contacted the shipowners or their agents to book hold space. The stevedore's office and the Port Authority will have allocated space where the goods may be stored while awaiting loading. If any goods are classed as hazardous — explosive, corrosive or highly flammable — the Harbourmaster's office will also have notified the Fire Brigade.

The ship's first contact with the port comes when she is boarded by the Pilot. When he has brought the ship to the port limits, she is often met by tugboats.

The shipowners or their local agents will have ordered a work force from the stevedore's office well ahead of time. Foremen, dockers and crane drivers go into action to discharge the vessel; but the bustling scene of crane jibs swinging with their loads from ship to quay, of dockers hooking and unhooking slings, and of trucks shuttling back and forth between quay and sheds, is only one aspect of the total activity. Behind the scenes, reams of documents are being typed out and hundreds of phone calls made. The tallyman checks off his list of goods to be discharged; the Customs require "cargo manifests"; bills of health must be presented; the ship must be fuelled, watered and stored; onboard repairs may be needed; certain crew members may be paid off and their reliefs signed on; etc.

It is usual for manufacturing companies to entrust the forwarding of their goods to freight and forwarding agents. The forwarding agent owns no trucks, railcars or ships himself — but he knows how to arrange the movement of goods all over the world.

He arranges road and/or rail transport at the docks at the right time. He books space for the cargo with the shipping company or its agent. The latter tells the stevedore's office when the ship is due to arrive, how much cargo is to be discharged and how much is to be loaded aboard.

The forwarding agent is the cargo owner's representative at the port and it is his job to watch over the interests of the shipper or consignee. The forwarding agent is an important link in the overall network of distribution responsible, as he is, for getting the right goods to the right place at the right time and the right price. He plans transportation and arranges for trans-shipment, Customs clearance, etc.

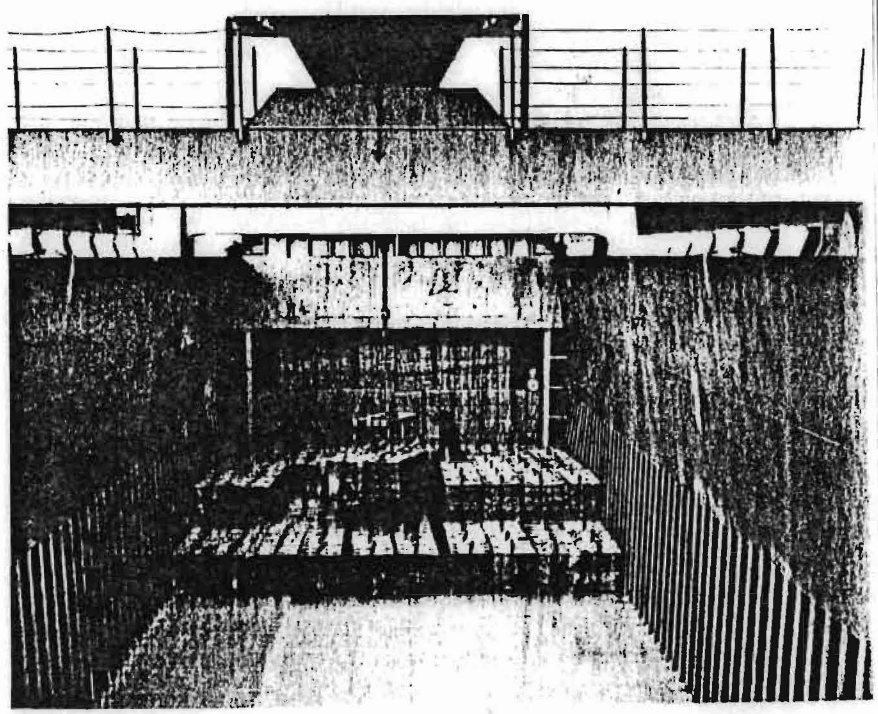
In its simplest form, the task of the forwarding agent in a routine import operation is to relieve the shipping company of the imported goods and to pay the freight and unloading charges without delay. There are also

Customs formalities to be handled; Customs duties, excise taxes and harbour dues to be paid; and suitable transport to be provided for the forwarding and distribution of goods.

In connection with trans-shipment the agent is often required to arrange, on his principal's behalf, for interim storage of the goods and for marking, repacking, insurance, etc.

At the exporting end of the chain the forwarding agent books goods aboard a suitable outward bound ship and completes the necessary export documents such as Customs and shipping documents, consulate invoices, etc.

The transportation business is a major customer of postal and telegraphic services all over the world. Communications are being forced to move with the times; the fast container ships that cross the North Atlantic in 4-6 days overtake the mail, so the shipping documents are transmitted by telex and facsimile.



Study Questions: Seaports

1. Define:
   a. Seaports
   b. Intercontinental trade
   c. Quay
   d. Hinterland
   e. Turnaround time
   f. Pilot
   g. Forwarding agent
   h. Customs (duties/customs)

2. What effect on seaports do the constant changes of modern transportation have? Give specific examples.

3. What are some of the ramifications of port congestion, both seaward and landward? Explain with one example.

4. To achieve "optimum economic status", a port must have a well integrated system. Explain.

5. List and comment on the costs of sea transportation. How does this compare with other types of transportation?

6. What are the expected "new and untried techniques" of sea transportation since the late '70's?

7. What is the general/overall aim of transportation development? Give an example.

8. Compare with an example for each - sea, rail, and road transportation the tranpsort of cargo.

9. Discuss the interrelationships of the transportation systems in both the developed and the developing regions of the world. If you were a planner/engineer in which region would you rather work?

10. Explain the following sentence using examples: "... the expansion of the industrialized world over the past century would not have been possible without the enormous advances that took place in the technology and economic of sea transport." What is this impact on the developed world? What do you think this impact will be on the developing world?

11. Who owns a seaport? How is the seaport generally designed? Explain the variety of the hinterland.

12. Discuss the location, size, and cargo handling of:
    a. Singapore
    b. Rotterdam

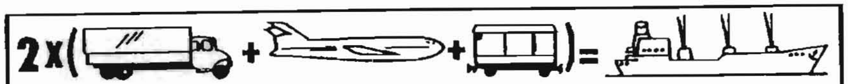
Study Questions: Seaports (concluded)

13. What effects do strikes have on ports? Cite two specific examples.

14. What are some of the fees one would entail in shipping oil from the Arabian Gulf (on a 300,000 ton oil tanker) to Rotterdam or to Gothenburg. Locate both cities.

15. Give examples and then explain why different types of traffic may pay different dues.

16. How long is the average Atlantic containership crossing? What impacts does this have on shipping generally?



The transportation work in ton-miles performed by ships sailing the world's oceans is twice as great as that carried by all the world's roads, railways and airways put together.

SOURCE: SHIPPING – HOW IT WORKS. THORSTEN RINMAN AND RIGMOR LINDEN. GOTHENBERG, SWEDEN. 1978.

Seaborne world trade

This world of ours has changed dramatically in the past one hundred years. On each continent, populations have migrated to rapidly expanding centres of industry where urbanized cultures have grown up with tremendous force as the result of billions of "cross-fertilisations".

Two lines of development, more than any others, have made this explosive growth possible and kept it going. One is the development of communication between people: mass-produced books, cheap newspapers, radio, magazines, television, etc. The other is transportation, which is also a form of communication; for regional transport, we now have built roads and railways and for international transport we have a global shipping network without which present-day trade would be impossible.

Until about a hundred and fifty years ago, nearly all ocean-going ships were mainly bearers of culture though, of course, the ships also carried cargoes — cargoes of great value. The function of world shipping today, however, is simply to supply industry with raw materials and to distribute manufactured goods all over the world.

Communication is thus the key to Man's progress during the past century. This book is about shipping, so let us quote a few figures to illustrate the importance of shipping to world trade: expressed in ton-miles or ton-kilometres the total transportation of goods by rail in the world amounts to only 20 per cent of the total transportation work effected by ships (and half of the world's rail transportation takes place inside the USSR). If we confine ourselves to international commerce, i.e. goods which cross frontiers, about 95 per cent of all goods are carried by water and this amounts to the astonishing total of 3,400 million tons per annum valued at US $1 140 000 million (in 1977).

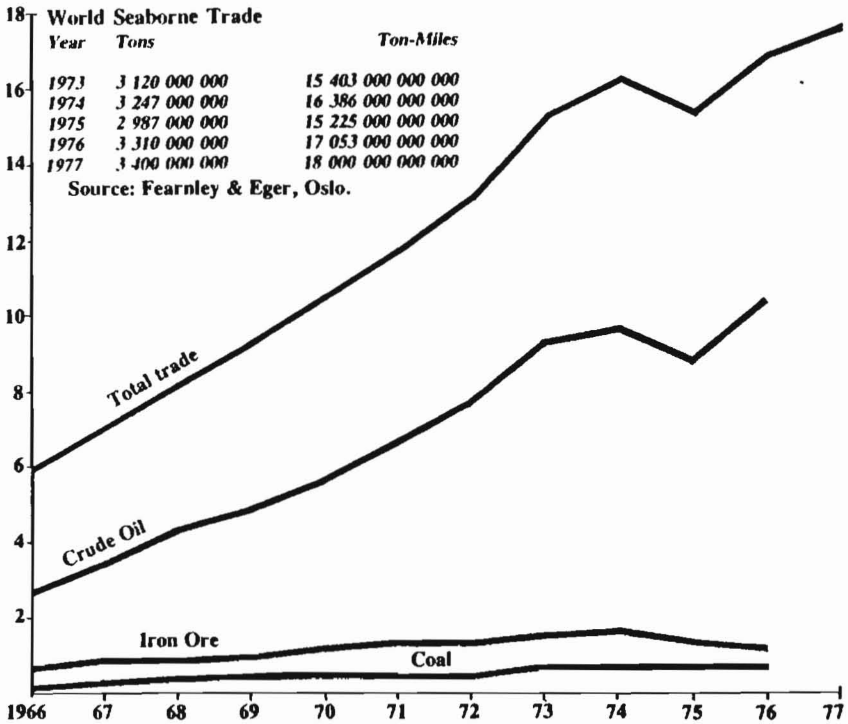
The object of this book is to try to describe world shipping as it operates in 1978 and, at the same time, to account for the historical roots that have most strongly influenced this remarkably efficient and ever-changing transport system. Current changes are analysed in an attempt to get a glimpse of the future.

In discussing the development of shipping, we must always bear in mind that the economical lifespan of a ship is under 20 years. In 1978, depending on its type, a large ocean-going ship costs anything between US$ 12 and US $ 120 million. It must, therefore be employed intensively during those twenty years to pay for itself. One of the problems here is that market cycles are sometimes ten years long and a ship that comes into service at the "wrong" time may never pay for itself. When considering the future of shipping it is irrelevant to acknowledge that all the continents of the world may once again, (in about 300 million years) be reunited into a single land mass, or that another ice age can be expected in a hundred thousand years from now. Even speculations on whether iron ore deposits will last 500 or 1 000 years lie outside our frame of reference. On the other hand it is highly relevant to try to establish the truth about the world's crude oil reserves. How great are the as yet officially unknown reserves of oil? And given that we can now pump up only a third of the oil from existing fields, what are the future prospects of economically recovering the other two-thirds from "worked-out" fields?

There is no doubt that world shipping will undergo a vigorous expansion during the next fifteen years but there is, however, a great deal of doubt about the immediate, short-term future of international shipping. Economic conditions, after several years of recession, are generally poor, and, seen from the perspective of 1978, even 1983 is uncertain.

Photo: Roland Svensson

World Seaborne Trade in MMMM ton-miles



In the longer view, by shipping standards (i.e. the rest of this century), the volume of world seaborne trade will double at least.

Another trend is the westward displacement of the centre of gravity of world shipping. At one time this centre lay in the region of the Mediterranean and Europe. It gradually shifted across the Atlantic, and in more recent times across the Pacific to the Far East. This migration will continue to follow the sun across the sea to South-East Asia.

The industrial development of the Third World carries tremendous implications for the future of shipping. The combination of fast-growing populations and rising standards of living can generate an enormous expansion of world seaborne trade.

More figures by way of illustration: the Third World exports 0.2 ton and imports 0.1 ton per capita per annum, whereas the industrialised regions of the world export 1.1 tons and import 1.4 tons per capita per annum. Note that these figures are in tons, and that the foreign trade of the Third World has hitherto comprised little other than cheap raw materials.

Even if population growth in the Third World were to stop completely and immediately, and if the Third World could double its seaborne exports in the next fifteen years, by 1993 the volume of exports from developing countries would equal the 1978 total volume of world shipping (excluding oil).

If the world's population increases from its present 4 billions (10^9) to 5.2 billions by about 1993 — and if seaborne trade per capita doubles in the same period — the volume of goods shipped in 1993 (excluding oil) will amount to 4 billion tons. This represents an increase of 270 per cent.

This development will be accompanied by a sharp rise in energy demand and, in the same time frame as we are using (up to 1990), the primary energy source will remain oil.

Rapid expansion of world seaborne trade in the future will, in no small degree, be a direct consequence of the growth of population and prosperity in the Third World. Such an expansion will create an urgent need for sensible, practical means of transportation.

Growth on the scale indicated here will not be accomplished as easily as was the expansion of world shipping in the 1950's and 1960's. It will no longer be a matter of hauling ever bigger volumes of homogeneous cargoes in ever bigger ships, but one of sophisticated, comprehensive and capital-intensive transport systems like the container systems which have been established on the North Atlantic and between Europe and Australia/Japan, and which are now being established between Europe and South Africa.

Raw materials

In the past few years the increase in shipments of oil and other raw materials has slowed down. Transportation of dry raw materials such as ore and coal has not been affected by the increase in economic activity between 1976 and 1978, due to the large stockpiles held by industry in 1976. In 1978 about 700 million tons of such raw materials were transported annually by sea. If the OECD forecasts of economic growth in various countries during the coming twelve-year period can be accepted, sea transport of these dry raw materials ought to have reached a volume of about 1,200 million tons by 1990.

Transportation of bulk goods is slow to react to market fluctuations; the effect on the freight market often takes a year or so to manifest itself.

If we study raw material resources we find that the supply of ore, coal, aluminium ores, etc. is virtually unlimited when considered against the background of the present rate of exploitation. The exploitable resources in the earth's crust are so vast that even at an accelerated rate of extraction they will last so far into the future as to make speculation about shortages inconceivable today. About half a billion (10^9) tons of iron ore are mined each year, while known exploitable deposits amount to hundreds of billions of tons. Much the same claims of unlimited supplies in the foreseeable future can be made of several other ores. Deposits have already been found which will last for hundreds of years, yet prospecting has, so far, only been conducted on a very limited scale. Huge deposits are known to exist in Africa, Asia, Antarctica, the Arctic, and in South America which, for various reasons, have not yet been officially "found".

General cargo

The term "general cargo" is used here to refer to all kinds of dry cargo not classifiable as ore, coal or grain. These cargoes — manufactured goods, intermediates, etc. — are carried in container ships, general cargo ships, reefer ships, small and medium sized bulk carriers etc. During the mid-1970's, annual shipments amounted to about one billion (10^9) tons and are expected to reach 1.5 billion by 1985.

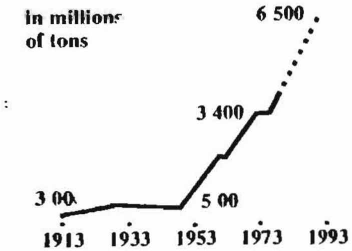
The markets for these cargoes react quickly to fluctuations in world economy. In the light of OECD predictions of growth in the GNP of various countries, a reasonable estimate of the growth rate of general cargo transportation lies in the region of 5.3 per cent per annum in the coming twelve-year period. These shipments fell somewhat in 1975, but increased in 1976 by 8 per cent — a growth rate which declined in 1977 and 1978.

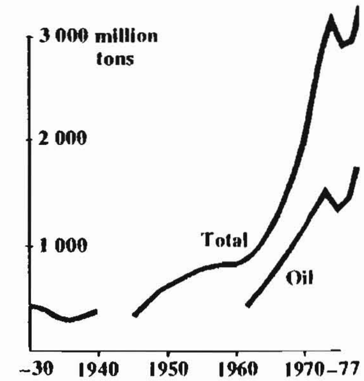
This is how seaborne trade in billions of tons may develop in the years to come. During the period 1973–1993 it has been calculated that oil transportation will expand at a rate of 5 per cent per annum, and that dry cargoes will increase by a total of 100% per capita in the period ahead ending 1993 – these figures also allow for the probable growth in population in the various parts of the world. The actual growth may be even more dramatic; the demand for oil transportation increased by 13 per cent in 1976 and by half that in 1977.

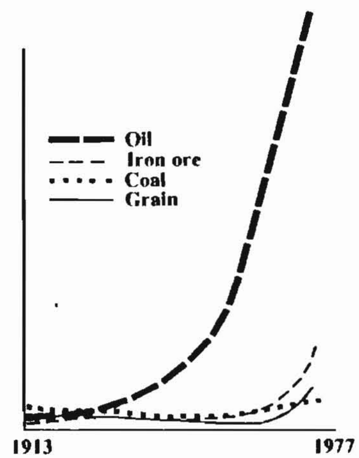
World seaborne trade expanded enormously during the 1960's – mainly because very large tankers and bulkers made long-distance sea transportation of low-priced products an economical proposition. It was this development that made possible the industrial expansion of Japan, which in turn led to such a marked increase in transoceanic trade.

At the beginning of this century, seaborne raw material cargoes consisted mainly of coal. The amount of coal transported in those days was about the same as now. Transportation of iron ore by sea has increased tenfold since before World War I, and grain transportation threefold – all expressed in ton-kilometres.

Seaborne trade







Oil

Study of the oil trade reveals a very strong growth in seaborne transportation. Crude oil production doubled in the ten years ending in 1973.

After an initial stagnation in 1974, followed by a decline in 1975, oil shipments rose by 13.5 per cent in 1976. This was a vigorous response to the temporary economic upswing and the rapidly rising demand for imported oil in the USA. Growth almost halved in 1977 when annual production was about 3 billion (10^9) tons. The OECD world economic forecast for the future suggests that oil shipments can be expected to increase from 1.4 billion (10^9) tons to 2 billion tons a year by 1985.

It is not improbable that oil and gas production will reach their peak at the end of this century, and then start to decline. When looking at *proven "official"* oil reserves, however, we should bear in mind that they have a tendency to be always enough to last for a third of a century. The oil reserves officially published every year have always — at current rates of production — been sufficient for 30 to 35 years.

Note the precision with which the oil industry has annually estimated oil reserves as equivalent to 30 — 34 years' consumption at the current year's production volume.

Year:	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Annual crude production in billions (10^9) of tons	1.5	1.6	1.7	1.8	2.0	2.1	2.3	2.5	2.6	2.8	2.9	2.7	2.9	3.0
Crude oil reserves published in the year in billions (10^9) of tons	46.5	47.9	53.3	56.8	62.9	73.2	84.1	87.0	90.4	85.4	97.3	89.6	87.5	87.8
Reserves forecast to last for further number of years with unchanged consumption	31.8	30.6	31.4	31.2	31.6	34.1	35.8	35.1	34.8	30.0	33.9	33.2	30.0	29.0
That is, oil reserves forecast to be exhausted by	1996	1996	1997	1998	2000	2003	2006	2006	2007	2003	2008	2008	2005	2006

Effects of population growth

The forces of development in the Third World will vary from nation to nation, depending — to put it in very simplified terms — on economic,

technical and social conditions. The economic conditions are naturally heavily dependent on the ability of the nation in question to generate capital. One of the most important technical conditions is the ability of the nation to build up an efficient transport system from the quayside to the ultimate domestic consumer. The social conditions are the results of population growth and political systems.

In 1977, seventy per cent of the world's population lived in developing countries — a few per cent more than ten years ago. If this trend continues until 1990, 80 per cent of the world's population will be living in what we now call developing countries.

There are now 4 billion (10^9) human beings in the world; twelve or thirteen years ago there were 3 billion (10^9) and by about the year 2000 there will be 6.5 billion, unless the population growth curve is broken for some reason before then. The growth rate has stayed almost constant at 2 per cent per annum for 25 years.

While seven out of ten people, now live in developing countries, only two out of ten live in industrialised "Western" countries, and one out of ten lives in a COMECON country, i.e. a state within the sphere of influence of the USSR. Population growth in China and the industrialised countries is relatively small, while the growth rate in South America, Africa, the Middle East and Asia varies between 2.3 and 2.8 per cent per annum. This has been the general pattern of population growth since 1965.

The ability of the earth not only to feed a growing population, and to yield enough food to banish starvation from the world of the future is more a social, economic and technical problem than a question of the absolute food-producing capacity of our planet.

In farm production, harvest follows harvest in an eternal cycle of renewal — whereas raw material production means digging up the irreplaceable resources of the earth. Farm production can be doubled in large regions of the world, for example in South and North America. In countries with a warm climate, increased use of fertilisers could boost crop yields substantially, and there are still vast areas suitable for farming where no plough has ever broken the soil. It will, however, take very heavy investment to adapt this virgin land to agricultural use.

The greatest area of cultivated land *in comparative terms* is to be found in Europe, where almost 30 per cent of all land is arable. The corresponding figure for Asia is almost 20 per cent and for South America 5 per cent. More than half the land area of Australia and South America consists of grazing land. We must also consider the sizes of the different continents, the intensiveness of farming, and the rate of production.

With the forecast increase of population up to the year 2000 (+2.5 billions) a quarter of a billion tons more grain will be needed than what we consume today. And those 250 million tons of grain will only suffice to keep the 2.5 billion (10^9) "extra" people marginally subsistent on a pure grain diet. Incidentally, 250 million tons of grain is twice the amount of grain now transported by sea in one year.

In simplified terms, a man needs a ton of grain a year to live well on meat, eggs, bread, etc. A man on a subsistence-level continent can just get by on a hundred kilograms of grain a year if he lives on a cereal-based diet.

Most of the world's raw materials are located on the industrialised continents, and these are also the continents which have surpluses of farm products. It is the underdeveloped continents which produce most of the luxury-type foodstuffs such as coffee, cocoa, bananas and sugar. Latin America produces 75 per cent of the world's bananas, 60 per cent of the world's coffee, 50 per cent of all sugar, 23 per cent of all meat and 17 per cent of all tobacco. Despite this, 100 million Latin Americans are undernourished by the standards of the industrialised world. Farm production in Latin America needs to be doubled within the next fifteen years to provide everybody on that continent with an adequate and healthy diet.

While trade in the industrialised world is mainly devoted to buying from and selling to other industrialised countries, exports from the Third World consist mostly of raw materials destined for industrialised countries. The situation is worse for some developing countries whose economy is based on a single commodity. Thus tin accounts for some 75 per cent of Bolivia's exports, while two-thirds of Chad's exports consist of cotton, 80 per cent of Cuba's consists of sugar, and two-thirds of Ghana's consists of cocoa.. Consequently, these countries are highly vulnerable to world market fluctuations.

There is, however, a general tendency for both production and consumption in the Third World to increase and to take a larger share of world production, and to some extent also consumption, of raw materials. On the other hand the industrialised world's share in production and consumption of manufactured goods and intermediates is rising. Another side of the picture is that the gap between rich and poor developing countries is widening noticeably. The growth of world prosperity is now concentrated in those few developing countries which enjoy particularly favourable circumstances.

The trends in world trade are that Africa's and Latin America's shares

of seaborne world trade are gradually diminishing, that the expansion of trade in the Socialist countries is slowing down, and that the industrialised countries are taking a growing share of world trade. Japan and South-East Asia, above all, are the most expansive centres of world trade.

Total exports from developing to industrialised countries amount to $5 billion per annum, of which the USA and the EEC take about a third each, Japan a quarter, and other countries the rest.

Only three per cent of the world's bulk shipments (oil excluded) go from one developing country to another. Two-thirds of all raw material exports come from industrialised countries.

For a hundred years the industrialised regions of the world have been responsible for most of the vigorous expansion of world seaborne trade – an expansion which accelerated during the 1960's and early 1970's.

In the foreseeable future it will also be the industrialised regions which will continue to generate the major share of transoceanic goods traffic. It is likely, however, that certain developing countries will eventually account for a relatively larger share of seaborne world trade, with consequential effects on the structure of the world's merchant fleets.

It has been said that, in the economic and social development of Third World countries the big bulk and crude carriers have been just as important as the printing press. The reasoning behind this assertion is that the big ships opened up the vast raw material deposits of Asia, Africa, South America, etc. The much cheaper transportation offered by the big ships made it economically feasible to haul cargoes of ore, coal and oil from hitherto virgin regions halfway round the globe to those industrialised countries hungry for raw materials. Two-thirds of all goods (except oil) loaded in Third World ports consists of bulk raw materials for industry.

World-wide industrial expansion was made possible by the sharp drop in the cost of transportation by sea. During most of the 1960's there was a depression in shipping which parallelled the technical developments leading to a transition to radically increased tonnage sizes and a consequent substantial improvement in the economics of transportation by sea. It was during this period that the huge raw material reserves of Australia, South America and the West Coast of Africa were opened up. It was then that the Middle East oil bonanza rocketed.

It must be recognized, however, that the big ships used, and still use, terminals designed to handle specific types of cargo, such as coal, ore or oil while the richer phase of economic, social and industrial development

— upon which the Third World is hopefully about to enter — calls for radically different types of ships and harbours i.e. liners of suitable size and other tonnage of the order of 3 000—40 000 tons.

Essentially, it is the industrialised regions of the world that regulate the pace of development in the Third World. The degree of hunger for raw materials in industrialised countries has a great effect on Third World export incomes. The degree of protectionism and support for unprofitable domestic industries in the industrial nations controls the growth of demand for industrial goods produced in the Third World.

Raw material imports by the industrial nations, and the willingness of those nations to open their domestic markets to the products of the Third World's industries will, thus, be crucial to the prosperity of millions of people in the developing countries. The volume of population growth is determined on the one hand by birth control and on the other by the decline in infant mortality and longer life expectancy that have been found to accompany rising standards of living.

World Trade in figures

We shall now try to recapitulate the points made in the foregoing chapter by quoting some figures.

The relationship between economic growth, world trade and world shipping is as follows: the economic growth of the industrialised nations of the world (measured in gross national product, GNP) advanced during the period from 1957 to 1974 at an average rate of 4.5 per cent per annum. Seaborne world trade increased during the same period by an average of 8 per cent per annum. The actual percentage figures varied widely with the level of economic activity, but the correlation between GNP on the one hand and seaborne trade on the other remained constant, i.e. seaborne trade expanded nearly twice as fast as GNP. No change in this correlation has taken place during the 1975-78 recession.

A similar correlation exists between GNP growth in industrial countries and oil consumption. And the remarkable thing is that this correlation was not disrupted by the so-called oil crisis. During 1976, global economic activity increased by about 5 per cent, while oil consumption rose by 8 per cent and seaborne oil trade by 13.5 per cent. The fact that during 1977/78 seaborne oil trade grew faster than oil consumption was connected primarily with dramatically increased US import requirements, and also with generally longer transport routes (the volume of seaborne oil trade being expressed in ton-miles).

Global GNP rose by 150 per cent from the mid-sixties to tl mid-seventies, the industrialised OECD countries accounting f three-fifths of the world total of GNP growth. The OECD predicts th GNP will rise by an average of 4 per cent per annum until 1985. Japa which is a member of the OECD, has forecast a domestic annual GN growth of 6 per cent, which matches the general impression that the mo expansive region of the world will be the Far East and South-East Asi The figures for GNP given here in various contexts are based on fix prices, and thus represent real growth with the effects of inflati eliminated.

Seaborne carriage of goods has assumed an increasingly important ro in the world's economy; it accounts for about 10 per cent of the world gross national product, and this share has been growing by almost o percentage unit per annum for the past few years. If this trend continue international trade will represent some 20 per cent of world GNP by tl end of the 1980's; for this growing volume of international trade will l carried in ships.

The future

The future development of sea trade will be marked by a somewhat slow growth rate for raw material transportation, but a faster rate of growth i shipments of manufactured goods and intermediates. Short-ha transportation will also increase.

As economic growth reaches the takeoff point in one large developin country or a group of smaller ones in a given region, there will be a rapi expansion of coastal traffic in that region. This "internal trade" wi provide employment for a growing fleet of ships under 40 000 tons. It is thi sector of world shipping which appears today to have the best prospec for expansion.

The oil crisis of 1973 broke a long-term trend reflected in an annu increase of 8 per cent in world trade and 10— 12 per cent in the demand f sea transport. The world entered a recession lasting several years, th blame for which has been laid unilaterally on tripled oil prices. Actually i is doubtful whether the rise in oil prices really caused the economi depression we are now trying to climb out of.

The rise in oil prices was preceded by drastic increases in raw materi prices and widespread stockpiling at sky-high speculation prices. The o crisis was moreover preceded by several years of currency unrest whicl really shook up world economy. Finally, the oil crisis occurred in a perio of general inflation which can be characterised as massive and which is not yet over.

Much of the chaos customarily blamed on the threefold rise in oil prices ought truthfully to be blamed on a shift of competitive advantage towards the Far East and South-East Asia, on unstable currencies and general inflation — but the present recession is perhaps more than anything else a consequence of psychological factors. The 1973 oil price rise was just the last straw that broke the camel's back. The balance will not be restored until the world has progressed far enough towards a brighter economic climate and stability to allow a complete recovery of self-confidence by industry, commerce and shipping. When this happens, and the wheels of industry start turning again, the world will have several years of stagnation to catch up on.

The next boom cannot be predicted from OECD figures and forecasts. It will come suddenly, when the psychological conditions are right. But in good times as in bad, it is world shipping that keeps world trade on the move. Expressing transportation performance in ton-miles, the world's mercantile fleets move twice as much goods as all the world's roads, railways and airlines put together.

World Bulk Trades in figures

Source: Fearnley & Eger

World Seaborne Crude Oil Trade

Year	*Tons*	*Ton-Miles*
1966	607 000 000	2 629 000 000 000
1967	672 000 000	3 400 000 000 000
1968	768 000 000	4 197 000 000 000
1969	871 000 000	4 853 000 000 000
1970	995 000 000	5 597 000 000 000
1971	1 068 000 000	6 554 000 000 000
1972	1 184 000 000	7 719 000 000 000
1973	1 365 000 000	9 206 000 000 000
1974	1 360 000 000	9 660 000 000 000
1975	1 259 000 000	8 882 000 000 000
1976	1 417 500 000	10 229 000 000 000

World Seaborne Coal Trade

Year	*Tons*	*Ton-Miles*
1966	61 000 000	226 000 000 000
1967	67 000 000	269 000 000 000
1968	73 000 000	310 000 000 000
1969	83 000 000	385 000 000 000
1970	101 000 000	481 000 000 000
1971	94 000 000	434 000 000 000
1972	96 000 000	444 000 000 000
1973	104 000 000	467 000 000 000
1974	119 000 000	558 000 000 000
1975	127 000 000	621 000 000 000
1976	127 000 000	591 000 000 000

World Seaborne Grain Trade

Year	*Tons*	*Ton-Miles*
1966	76 000 000	408 000 000 000
1967	68 000 000	380 000 000 000
1968	65 000 000	340 000 000 000
1969	60 000 000	307 000 000 000
1970	73 000 000	393 000 000 000
1971	76 000 000	406 000 000 000
1972	89 000 000	454 000 000 000
1973	139 000 000	760 000 000 000
1974	130 000 000	695 000 000 000
1975	137 000 000	734 000 000 000
1976	146 000 000	779 000 000 000

World Seaborne Iron Ore Trade

Year	*Tons*	*Ton-Miles*
1966	153 000 000	575 000 000 000
1967	164 000 000	651 000 000 000
1968	188 000 000	775 000 000 000
1969	214 000 000	919 000 000 000
1970	247 000 000	1 093 000 000 000
1971	250 000 000	1 185 000 000 000
1972	247 000 000	1 156 000 000 000
1973	298 000 000	1 398 000 000 000
1974	329 000 000	1 578 000 000 000
1975	292 000 000	1 471 000 000 000
1976	294 000 000	1 469 000 000 000

World Seaborne Phosphate Trade

Year	*Tons*	*Ton-Miles*
1966	27 000 000	96 000 000 000
1967	28 000 000	103 000 000 000
1968	32 000 000	119 000 000 000
1969	32 000 000	118 000 000 000
1970	33 000 000	116 000 000 000
1971	35 000 000	121 000 000 000
1972	38 000 000	135 000 000 000
1973	43 000 000	159 000 000 000
1974	48 000 000	168 000 000 000
1975	38 000 000	127 000 000 000
1976	37 000 000	125 000 000 000

World Seaborne Bauxite and Alumina Trade

Year	*Tons*	*Ton-Miles*
1966	23 000 000	55 000 000 000
1967	25 000 000	62 000 000 000
1968	26 000 000	70 000 000 000
1969	30 000 000	84 000 000 000
1970	34 000 000	99 000 000 000
1971	35 000 000	108 000 000 000
1972	35 000 000	109 000 000 000
1973	38 000 000	133 000 000 000
1974	42 000 000	158 000 000 000
1975	41 000 000	168 000 000 000
1976	42 000 000	158 000 000 000

Study Questions: Seaborne World Trade (concluded)

1. Compare sea and rail transportation. Note the status of rail transportation in the USSR.

2. Discuss some of the complex economic issues/problems that are a part of the shipping industry.

3. Illustrate how the center of world shipping has changed. What do you think will be additional facyors that till stimulate changes in the shipping industry in the 1980's?

4. Discuss some of the impacts the third world may have on trade. What impact will technology have?

5. Raw Materials
   a. Give examples of some of the raw materials transported by sea. Note the projected data for these same materials by the year 1990.

6. Comment on the supply of such raw materials. Give specifics.

7. Define "general cargo". What is the reaction of these cargoes to world market prices? Contrast this with raw material prices.

8. Seaborne Trade -- see graph
   a. Which products had an increase in seaborne trade during the 1913-1977 period?
   b. Note two reasons for this result.
   c. Illustrate from this material the interdependence of the world of the 1980's.

9. Oil

   Discuss the oil shipments in the following years:
   a. 1974
   b. 1975
   c. 1976

   What is the expected increase of oil shipments to 1985?

10. What is the projected outlook for oil from 1980 until the end of this century?

11. What are the major forces that will affect Third world developing countries? How do these forces relate to ports?

12. What percentage of the world's population lives in developing countries? Comment on the growth rate.

Study Questions: Seaborne World Trade

13. Discuss the resources of the farm and raw material production.

14. What is the projected increase of population by the year 2000?

    a. Relate this to food production (grain) and water transport.

    b. Location of world's raw materials.

    c. Luxury-type food stuffs.

    d. Fluctuations in the world market.

    e. Trends in world trade.

15. What has been the status of the expansion of world seaborne trade?

    a. In the industrialized nations.

    b. In the developing world.

16. What major changes occurred during the 1960's that effected shipping? Note specific changes.

17. To what extent does the industrialized world impact the pace of Third world development?

18. Compare the relationship of economic growth of the industrialized nations and of seaborne trade.

19. What was the global GNP rate in the '60's and '70's? What is its expected rise? Which country expects the greatest rise? Relate this to seaborne transportation.

The Future

20. What are the future expectations for:

    a. Raw material trnasportation.

    b. Manufactured goods.

    c. Short haul goods.

    d. Coastal traffic (note the size of the ships).

21. What reasons are given for the current crisis in world economy besides oil prices? Explain your reactions to this reasoning.

22. How significant is water transportation in the world economy?

23. Graph: Seaborne World Trade p. 26

    a. Study the World Bulk Trade Figures. Which resource illustrates the greatest volume in world trade?

    b. Which resource demonstrates the greatest fluctuations?

    c. Which resource statistics do you think will change more in the next 15 years? What impacts will this have?

NEW ENGLAND PORTS

Student Activities

Directions: The following activity is divided into three sections: a map assignment, research segment, and conclusions.

Complete the entire assignment.

Research/Map Assignment

Locate each of the following ports on the map of New England that is provided. On an attached sheet of paper, complete the information that is requested after the listing of the ports.

Historic Ports

1. Boston
2. Salem
3. Newburyport
4. New Bedford
5. Gloucester
6. Nantuckett
7. Portland
8. Portsmouth
9. Providence
10. New London
11. Essex
12. Mystic
13. New Haven
14. Bridgeport

For each port, complete the following information:

1. Name of port ______________
2. State of location ______________
3. Major dates as a maritime center ______________
4. Main significance of this port (include specific dates)
Or ______________
5. Main contribution of this port -
____

EXTRA CREDIT

Select one port. Complete the requested information :

1. What is the general status of this port city in the 1980's? Give specific tonnage, cargo handled, and frequency of shipments.
2. Briefly define each of the following types of cargo. Determine which type of cargo is handled at this port:
   a. Container
   b. Break bulk
   c. Bulk (dry, ores, minerals)

NEW ENGLAND PORTS

Student Activities

Extra Credit Assignment (concluded)

3. What is the value of the cargo shipped into and from this port? Give specific dates.

   a. Imports ________________

   b. Exports ________________

4. What is the approximate hinterland of each port? By which method of transportation is this port served? (water, rail, highway?)

5. Do any projected plans exist for the activities of this port? Explain why in either case.

6. Determine whether other ports in the area or other means of transportation add or detract from the economic viability of this port. Give specific references.

N.B. The information requested in this assignment may be obtained through the Port Management Office of each Port. You may also write to the specific Chamber of Commerce in each city.

Make certain that you request specific information in your communication. You may also ask for any printed information and pictures of the port you choose to study.

NEW ENGLAND PORTS

Student Activities

A. Directions: Select one port from the following list and complete the requested information:

1. Boston
2. Salem
3. Gloucester
4. New Bedford
5. Portland
6. Portsmouth
7. Providence
8. New Haven

B. Complete the following for the port you have selected

1. Map location
2. Main cargo imported/exported from this port
3. Major activity/tonnage of this port
4. The Port fees
5. Dockage fees
6. Turnaround time (average) and the significance of this.

C. Complete the following for your selected port:

1. Ownership of this port is:
2. This port is managed by
3. The economic value of this port is established at
4. The extent of this port's hinterland is

D. If the following information is available, explain the projected plans for the port you have studied.

1. Expansion plans - projected dates
2. Maintenance schedule (dredging, channel improvements, etc.)
3. Revitalization of the port and its facilities

CHAPTER 7

DEEPWATER PORTS

Principal Agency: Department of Transportation
Principal Legislation: Deepwater Port Act of 1974

On December 17, 1976, Secretary of Transportation, William T. Coleman, approved the applications of LOOP, Inc. and SEADOCK, Inc. to construct deepwater ports off the coasts of Louisiana and Texas. Despite conditional approval, it is not yet clear that these deepwater ports will be constructed. However, the use of coastal or ocean waters for the construction and operation of deepwater ports is a coastal water use that deserves special consideration by all coastal states.

The continued import of foreign oil into U.S. coastal waters and future expansion of vessel transportation of materials will require major modification of the coastal environment.[1] The issue is not related strictly to the shipment of oil, although that has been the focus of most initial plans. The general problem facing most ports and waterways is lack of sufficient depth to accommodate a new generation of large ships, especially the 100,000-500,000 deadweight ton (DWT) supertankers. If coastal waters are to serve in part as a means for continued or increased economic development, there will be a growing demand for deeper and wider navigational channels. The impact of such modifications, which might include Great Lakes lock systems, harbors, ports, navigational channels and the construction of offshore facilities, could be significant. One strategy that has been increasingly advocated in the United States since the late 1960s has been the construction of some form of port facility in deep water, as an alternative to deepening the channels and harbors closer to shore. Transfer of materials from this deepwater port to land would take place either through pipelines or by small coastal vessels that would not require major expansion of present channel depths.

While it is not clear what size tankers will be, due in large part to changing economics and the reopening of the Suez Canal, more than 55% of current world tanker capacity is in vessels of 100,000 DWT or larger. A principal reason for the greater use of larger tankers in recent years is cost. A 50,000 DWT tanker, of the type that typically serves such harbors as New York and Delaware Bay, averages 750 feet in length, 100 feet in width and 40 feet in draft. A 250,000 DWT tanker is typically 1,100 feet long and draws 70 feet of water. The key feature of the larger vessel is that it can carry five times as much oil at about half the price per barrel over long routes.[2] A saving that approaches 50% is a very strong stimulus both for private investment in the construction of such vessels and in consumer support for hopefully lower fuel costs.

A major problem with such vessels is that they are too large to operate in United States coastal waters. With the exception of Puget Sound, no port on the west coast has a depth exceeding 55 feet. The deepest port on the gulf coast is 40 feet, and there are not ports more than 45 feet deep on the east coast. Long Beach and Los Angeles harbors in California and Puget Sound are the only three U.S. ports that can accommodate tankers of more than 100,000 DWT.[2]

Delaware Bay has a fairly typical delivery system. More than two thirds of mid-Atlantic refinery capacity is in Delaware and New Jersey, and tankers must travel up the Delaware Bay and into the Delaware River to discharge their oil cargo. The December 27, 1976, spillage of 134,000 gallons of oil by the tanker Olympic Games in the Delaware River illustrated the present and potential hazards of such a delivery system. In many instances their delivery routes are in nearshore coastal waters where especially sensitive and important breeding grounds for finfish and shellfish exist, and where many shore-based coastal water activities take place.

Since the controlling depth of the Delaware River is 40 feet, large tankers now anchor inside Delaware Bay to pump their oil into barges or small tankers for final delivery to the refineries. This "lightering" process is commonly used in most coastal waters. In some instances the entire cargo is tranferred; at other times the cargo is partially transferred and the large tanker then is able to proceed, at reduced draft, into otherwise limiting navigation channels.

An example of what this might involve is given in the Office of Technology Assessment (OTA) Coastal Effects of Offshore Energy Systems report. The Japanese 191,000-DWT tanker *Yasutama Maru* arrived at the Big Stone Beach tanker anchorage in Delaware Bay on April 28, 1974. To lighter her cargo of 1,283,865 barrels of oil, it required 15 separate lightering operations, involving four trips of a 25,000-DWT tanker and 11 barge voyages to and from the Big Stone Beach anchorage. The reason for deepwater port support is reflected in a comment by the president of the Philadelphia Maritime Exchange who used the above example in testimony before the Delaware General Assembly. As he observed:

> "How much better and safer this could have been handled under the controlled conditions of a deepwater port which would permit a tanker to tie up to a platform, transferring its cargo into a pipeline, in a single operation, moving the oil via the pipeline direct to the refinery."[3]

For most coastal waters, a single-point mooring (SPM) system appears to be the most appropriate deepwater port facility. There are two basic types of SPM: the Catenary Anchor Leg Mooring (CALM) and the Single Anchor Leg Mooring (SALM), which OTA concluded in its analysis to be the safer of the two.[4]

To date, SPMs have had an impressive record of performance. More than 130 SPMs have been installed throughout the world since 1959.[5] The average oil spill rate at such terminals has been less than one barrel for every one million barrels handled, and it has been suggested that by using Very Large Crude Carriers (VLCC) in conjunction with deepwater ports that the number and volume of oil spills presently occurring with transhipment could be reduced by as much as a factor of ten.[5]

While deepwater ports of the SPM or other type appear to offer substantial reduction in oil spill hazard, especially where coastal waters are presently crowded, they have not been widely accepted by coastal states. By the early 1960s, considerable interest in the concept had emerged in the United States, and several projects were designed. The Corps of Engineers evaluated possible deepwater port sites in New York Bay, Delaware Bay, Cheasapeake Bay, the Mississippi River Delta, Freeport, Texas, Los Angeles/Long Beach area, San Francisco Bay and Puget Sound.[1] The Deepwater Port Act of 1974 reflected a strong interest in this concept.

However, several states expressed partial or total opposition to such projects. In 1971, Delaware passed a Coastal Zone Act which specifically precludes the construction of any further heavy industry, including offshore unloading terminals. New Jersey has also expressed reservations concerning such projects. The construction of a deepwater port represents a major financial investment, and it is possible that such projects will not be constructed in less than a supportive political climate. Both the OTA study and the Department of Transportation LOOP Environmental Impact Statement conclude that there is little chance of a major deepwater port project being constructed within the eastern seaboard:

> "Over the past ten years, about 1.7 MBD of refining capacity proposed for the East coast has been rejected by local, regional, state or federal authorities or referenda; and 13 different proposals to construct deepwater port facilities have either been rejected or indefinitely postponed. Therefore, no deepwater port of a scale sufficient to divert significant quantities of crude oil from the Gulf Coast is anticipated or assumed for the U.S. East coast.[6]

However, as offshore development increases, coastal ports may become more crowded and potentially dangerous. And the full impacts of the energy shortages of the 1970s are not yet clear. It seems possible that conditions might at some point change sufficiently so as to stimulate further consideration of deepwater port construction in many coastal areas.

PRESENT REGULATORY SYSTEMS

Within State Waters

The Deepwater Port Act of 1974 applies only to waters outside the territorial sea, and does not affect deepwater ports that might be constructed within the more adjacent coastal waters. For such projects, within such coastal waters, the coastal state would have primary jurisdiction, which it might exercise quite effectively through a coastal zone management program. The state could justify such regulation through its ownership of submerged lands, its widely recognized police powers, the provisions of the Submerged Lands Act and the Coastal Zone Management Act of 1972.

The U.S. Army Corps of Engineers and the Coast Guard would also be involved in any coastal waters port project. Under authority of the Rivers and Harbors Act of 1899, the Corps has responsibility for insuring that such projects do not interfere with navigation. The Coast Guard, aside from mandates to facilitate navigation, would be specifically involved under the Ports and Waterways Safety Act. The federal Environmental Protection Agency and the Corps of Engineers might have further involvement, if such a project involved water disposal of dredge spoil.

To coordinate these diverse authorities, the coastal state could make creative use of its coastal management program, acting as a lead agency in processing the project proposal. In establishing such a control system, the coastal states might consider patterning their regulations after those of the Deepwater Port Act.

Beyond Coastal Waters

The Secretary of the Department of Transportation has been given the responsibility for coordinating deepwater port projects beyond the territorial sea under the provisions of the Deepwater Port Act of 1974. The first two proposals processed under the provisions of this Act (LOOP and SEADOCK) received conditional approval from the Secretary of Transportation in December, 1976.

The Act and the regulations that have been promulgated under its authority establish a comprehensive review process for each deepwater port project.[7] This process may have a more general application for other types of activities proposed for coastal waters.

The Act and associated regulations establish a 45-day review process during which coastal states have an opportunity to comment upon the project. Unless a coastal state already has a comprehensive coastal zone management program in place, and considerable information on coastal water resources, it may not be able to realistically respond within that time frame.

The license process includes two steps. First a detailed application, including information specified in the rules and regulations, is prepared. Then it is reviewed by states, federal agencies and interested members of the public.

THE ROLE OF THE STATE

The Deepwater Port Act and associated rules provide for state involvement at several points in this review process.

Section 4(d) requires that if a coastal state intends to construct a deep draft channel and harbor, that an offshore deepwater port license cannot be granted until the Secretary of Transportation evaluates the relative benefits of each alternative and also considers if the two are compatible or mutually exclusive. Through this provision, the state gains assurance that a deepwater port beyond its jurisdiction will not be constructed in direct competition with a deep draft port proposed for coastal waters.

Section 5(g) requires that at least one public hearing on the project will be held in each adjacent coastal state.

Section 5(h)(1) requires that an applicant shall reimburse an adjacent coastal state for any costs incurred in processing an application.

Section 5(h)(2) allows adjacent coastal states to fix reasonable fees for the use of a deepwater port facility. Any state in which land-based facilities directly related to a deepwater port facility are located may set reasonable fees for the use of such land-based facilities.

Section 5(i)(2)(A) requires that if more than one application for a particular area is submitted, then the license shall be issued to an adjacent coastal state or combination of states if they are among the competitors.

Section 4(c)(10) requires that the adjacent coastal state to which the deepwater port is to be directly connected by pipeline must have developed or be making reasonable progress toward developing an approved coastal zone management program.

Section 9(b)(1) is of critical importance. It stipulates that the Secretary of Transportation "shall not issue a license" without the approval of the governor of each adjacent coastal state. This section also allows the governor of an adjacent coastal state to identify aspects of the project which are inconsistent with its programs relating to environmental protection, land and water use, or coastal zone management. Under such circumstances, the Secretary can make the granting of a deepwater port license conditional upon alterations that will make the project consistent with such state programs.

DETERMINATION OF "ADJACENCY"

Section 9(b)(1) of the Deepwater Port Act gives the governor of "adjacent" coastal state veto power over a license application for a deepwater port project in federal waters. It also affords adjacent coastal states a special status which gives their suggestions and concerns a greater impact upon the decision process. It would be to the advantage of any state near a proposed deepwater port to achieve this designation.

Section 9(a)(1) of the Act specifies the criteria to be used for a designation of adjacency:

> The Secretary, in issuing notice of application pursuant to Section 5(c) of this Act, shall designate as an "adjacent coastal state" any coastal state which (a) would be directly connected by pipeline to a deepwater port as proposed in an application, or (b) would be located within 15 miles of any such proposed deepwater port.

Section 148.217 of the rules and regulations associated with the Deepwater Port Act provides a mechanism by which coastal states that have not been designated as adjacent coastal states can request such a designation. Such a request must make a claim that the proposed deepwater port represents a risk of damage to the coastal environment of the requesting state that is equal to or greater than the risk posed to a state directly connected by pipeline to the proposed port facility. In its evaluation of deepwater ports the Office of Technology Assessment observed that if a deepwater port was proposed for the east coast, the close proximity of several states would probably generate several formal requests for an adjacent coastal state designation from the Secretary of Transportation.[8]

Florida is the first state to have sought such a designation under the provisions of the Deepwater Port Act. Concerned about increased tanker traffic that would be generated by the SEADOCK and LOOP proposals, Florida claimed that increased vessel passages through the straits of Florida justified an adjacent state designation. The Department of Transportation disagreed. The Coast Guard and the Office of Coastal Zone Management developed conflicting conclusions as to the merits of Florida's claim, and Florida sought judicial relief. Eventually an accommodation was achieved, and the case dismissed. Florida secured a promise from the Secretary of Transportation that all of that state's concerns would be reflected in conditions imposed upon the licenses. It is difficult to determine whether Florida warranted adjacency designation under the intent and language of the Deepwater Port Act. But the adjacency provisions did allow a mechanism by which the state was recognized as having a legitimate interest in the federal licensing decision, even if the extent of that interest must, of necessity, be determined on a case by case basis.

REFERENCES

1. Institute for Water Resources. *U.S. Deepwater Port Study,* U.S. Army Corps of Engineers (August 1972), p. 5.
2. Office of Technology Assessment. *Coastal Effects of Offshore Energy Projects* (1976), p. 173.
3. *Ibid.,* p. 175.
4. Office of Technology Assessment. *Coastal Effects of Offshore Energy Projects* (1976), pp. 188-196.

5. Flory, J. "Oil Ports on the Continental Shelf," in *Oceanus.*
6. Department of Transportation. *Final Environmental Impact/4(f) Statement: Loop Deepwater Port License Application,* p. 5.
7. *Federal Register* (November 10, 1975).
8. Office of Technology Assessment. *Coastal Effects of Offshore Energy Projects* (1976), p. 195.

RECOMMENDED READINGS

1. *Deepwater Port Act of 1974* (Public Law 93-627) 33 U.S.C., pp. 1501-1525.
2. Department of Transportation. *The Secretary's Decision on the Deepwater Port License Application of LOOP, Inc.,* Washington, D.C. (December 17, 1976).
3. Department of Transportation. *The Secretary's Decision on the Deepwater Port License Application of SEADOCK, Inc.,* Washington, D.C. (December 17, 1976).
4. Institute for Water Resources. *U.S. Deepwater Port Study.* Department of the Army, Corps of Engineers (August 1972), volumes 1-5.
5. Office of Technology Assessment. *Coastal Effects of Offshore Energy Systems* (November 1976), volumes 1,2.
6. U.S. Coast Guard. "Deepwater Ports: Regulations on Licensing Regulations and Design Construction, Equipment and Operations Requirements; and Proposal on Site Evaluation." *Federal Register* (November 10, 1975).
7. U.S. Coast Guard. *Environmental Impact Statement: Deepwater Port Regulations (Final)* Deepwater Ports Project, Department of Transportation (1975).
8. U.S. Coast Guard. *Final Environmental Impact/4(f) Statement: LOOP Deepwater Port License Application,* Department of Transportation (1976).
9. U.S. Coast Guard. *Final Environmental Impact Statement: SEADOCK Deepwater Port License Application. Executive Summary. Department of Transportation* (1976).
10. U.S. Coast Guard. *Guide to Preparation of Environmental Analyses for Deepwater Ports,* Department of Transportation (1975).
11. U.S. Coast Guard. *Recommended Procedure for Developing Deepwater Ports Design Criteria,* Department of Transportation (1975).

SOURCE: COASTAL WATERS: A MANAGEMENT ANALYSIS. JOHN M. ARMSTRONG AND PETER C. RYNER. ANN ARBOR SCIENCE. MICHIGAN: ANN ARBOR.

CHAPTER 8

TANKER SAFETY

Principal Agency: U.S. Coast Guard (DOT)
Principal Legislation: Ports and Waterways Safety Act of 1972

The regulation of tanker traffic in coastal waters is as complex as any coastal water use management issue, and perhaps typifies better than most issues the potential disparity between a relatively narrow-focus federal regulatory program and a state's effort at comprehensive coastal water planning and management as part of its coastal zone management program.

During 1976, the potential hazards of tanker accidents became dramatically evident. Congressional hearings as well as new state and federal legislation followed from a major series of tanker accidents in December, 1976, and January, 1977.

1. December 15–The tanker, Argo Merchant, ran aground in Nantucket Sound and within six days had spilled 7.6 million gallons of oil.
2. December 17–The tanker, Sansinena, exploded in Los Angeles Harbor after having unloaded more than 500,000 gallons of fuel oil.
3. December 24–The tanker, Owsego Peace, spilled 2,000 gallons of oil into Thames River near Groton, Connecticut
4. December 27–The tanker, Olympic Games, ran aground in Delaware River, spilling 134,000 gallons of oil.
5. December 30–The tanker, Grand Zenith, with 8.2 million gallons of oil, disappeared 300 miles east southeast of Cape Cod.

6. January 4—The tanker, Universe Leader, with 21 million gallons of oil, went aground off Salem, New Jersey, to avoid a collision with the tanker Texaco California, carrying 7 million gallons of oil.

Eighty percent of vessel casualties occur within coastal and harbor regions, and oil spill cleanup costs are estimated at $30,000,000-$35,000,000 per year.[1] It is a major problem that is intensifying in severity; 1976 was a record year for oil spills. Total oil imports to the United States are expected to increase as much as 70% by 1980.[2]

This inevitably means more tanker traffic and an increased danger of accidents. The size of potential oil spills has also greatly increased. In 1955 the largest tanker afloat was the Spyros Niarchos with a capacity of 47,470 DWT. In 1973, a 477,000-DWT tanker, Globtik Tokyo, was launched[3] and there is a possibility that even larger tankers will be constructed.[4] Continued reliance upon tanker transport is in part assured by the announced intentions of Canada to cease all sales of oil or gas to this country by 1981. This problem is not restricted to oil tankers. There are also problems associated with the shipment of liquid natural gas (LNG) and liquid petroleum gas (LPG), both of which represent different and in some ways greater problems than oil. Globtik Tankers USA just recently signed a letter of intent with the Newport News Shipbuilding and Drydock Company for the construction of three nuclear-powered, 600,000-DWT oil tankers. These nuclear tankers may represent even further management issues.

CURRENT PROBLEMS

1. Some 94% of petroleum imported into the United States is carried by foreign-fleet vessels. Many of them, under "flags of convenience," are in questionable operating condition, often improperly equipped, and operated by improperly trained crew.[5] With projections of a major expansion in tanker traffic, there is justification for the concern that present traffic control systems may not be sufficient.

2. While energy matters are of major national and state concern, coastal waters now and in the future must meet a variety of needs. Attempting to accommodate these other uses may be complicated by growing tanker traffic. OCS oil and gas development, deepwater ports, floating nuclear power plants and other offshore surface and submerged uses are increasing at the very time when oil imports are expected to increase. Each of the structures associated with these expanding activities represents a potential hazard to tanker traffic.

3. If an oil tanker spills its cargo, the ability to prevent that cargo from causing major water and shore damage appears still to be greatly limited, as demonstrated during the Argo Merchant spill. Further, the potential destruction of an LNG tanker is considerable. The nature and severity of these potential impacts suggest that tanker traffic may be incompatible with some other coastal uses or specific coastal natural systems.

4. Congress has declared that energy production is in the national interest. The Coastal Zone Management Act, as amended, is both implicit and explicit in suggesting that approved coastal zone management programs must provide some degree of accommodation to energy-related activities. It is unrealistic to consider the exclusion of oil or LNG tanker traffic from coastal waters. Yet any accommodation, especially during the present period of tanker traffic increase and the growing importance of coastal waters for other uses, raises a series of major problems.

5. The Coast Guard, which through the Ports and Waterways Safety Act of 1972 has principal regulatory authority over tanker safety in coastal waters, has often stated the position that unilateral tanker safety standards might harm international relations and that regulation through the Intergovernmental Maritime Consultative Organization (IMCO) or another international group might be more appropriate than attempting to set our own national standards.[6]

METHODS OF IMPROVED TANKER SAFETY

Several recent studies and reports have suggested a series of improvements in tanker construction and operation designed to decrease negative impacts of tanker traffic in coastal waters.

While there are individuals and groups who question the need, effectiveness or economic consequences of enforcing such standards, it would seem that several or most of these improvements will be required within the near future.

1. Require tankers to have double bottoms or double hulls to provide added protection against spillage if grounding or collision occurs.
2. Require inert gas systems to reduce risk of tank explosions.
3. Require segregated ballast tanks so that oil from cargo tanks is not flushed into coastal waters along with ballast waters.
4. Require better steering and propulsion systems, including double rudders and/or double boilers to provide more control and backup during equipment failure.
5. Require better navigation equipment and information.
6. Insure better training of officers and crew, perhaps through the type of testing and licensing that airline personnel must undergo.
7. Increase inspection and maintenance on tankers, especially those more than 10 years old.[4,5]

No matter how many structural or regulatory improvements are made, increased tanker traffic in crowded coastal waters will probably continue to represent a major risk to other coastal water uses.

Long-range options may exist: aside from reducing our need for imported oil and liquified gas, new transportation systems might be established, such as deepwater ports. Traffic would then be concentrated in special areas removed from high-traffic, heavy-use coastal waters. This option, which is discussed in Chapter 9, tends to shift patterns of tanker traffic rather than diminish it. However, for many coastal areas, such as Puget Sound, it may represent a reasonable alternative to increasing numbers of small- and medium-sized tankers.

But even with this type of solution, it can be expected that most coastal states will be faced with the problem of accommodating increased tanker traffic within their coastal waters in such a way as to protect the coastal zone and also allow for the expansion of other coastal uses with which tanker traffic might conflict.

EXISTING REGULATIONS

The principal regulatory authority for tanker safety in coastal waters is the Ports and Waterways Safety Act of 1972. New regulations affecting the implementation of this Act have been issued by the Coast Guard in recent years. They include:

1. "Rules for the Protection of the Marine Environment Relating to Tanker Vessels Carrying Oil in Bulk," *Federal Register* (December 13, 1976); and
2. "Navigation Safety and Vessel Inspection Regulations," *Federal Register* (January 31, 1977).

These regulations require that both foreign and domestic vessels engaged in U.S. coastal commercial trade must have segregated ballast tanks and, except under special conditions, may not carry ballast water in an oil fuel tank.

Any oil residue from tank washing must be kept in slop tanks, and discharge of this material is not allowed within 50 miles of the United States coast. These structural and operational regulations apply to all new vessels constructed after January 1, 1977. Also required under the new regulations are certain tests of vessel systems prior to entering a U.S. port, and improved navigational equipment. In future, Loran C and collision avoidance equipment may be required.

REGULATORY AUTHORITY

The Ports and Waterways Safety Act provides the U.S. Coast Guard with full authority to establish traffic regulatory systems, vessel and equipment standards, rules of operation and traffic control networks, including zones of travel, direction and speed.

Coastal states are not preempted from establishing safety regulations.

> "...nor does it (Act) prevent a state or political subdivision thereof from prescribing for structures; only higher safety equipment requirements or safety standards than those which may be prescribed pursuant to this title." [Section 102(b)]

However, as discussed in Chapter 2 on Jurisdiction, there are certain rules that might affect a state's ability to establish such regulations. While this Act may not preclude stricter state regulation, the Constitution reserves for Congress affairs dealing with interstate commerce. Also, in the Coastal Zone Management Act of 1972 states are charged with giving full consideration to the "national interest" and insuring that political subdivisions of the state do not unreasonably preclude developments of regional or national benefit.

New amendments to this Act have been introduced by Representative Studds. The amendments would greatly strengthen Coast Guard authority and responsibility:

H. R. 3796: Ports and Waterways Safety Act of 1977 and Amendments

Title I

Sec. 101(a)(1) Establish, operate, and maintain vessel traffic systems of services. . . .

Sec. 101(a)(2) Require any vessel, which operates within waters subject to any vessel traffic system or service, to utilize or comply with any such system or service, including requiring the installation and use of any electronic or other device necessary for such utilization or compliance.

Sec. 101(a)(3) Control vessel traffic by:
- (a) specifying times of entry, movement, or departure; including if necessary restriction of passage to daylight hours;
- (b) establishing vessel traffic routing schemes;
- (c) establish draft, vessel size and speed limitations, and vessel operating conditions; and
- (d) restrict operation, in any hazardous area or under hazardous conditions, by any vessel which has particular operating characteristics or capabilities; in a manner deemed necessary for safe operation under the circumstances.

Sec. 101(a)(4) Direct the anchoring, mooring, or movement of any vessel when necessary to prevent damage to or by that vessel or its stores, cargo, supplies, or fuel.

Sec. 101(b) The Secretary shall establish, operate, and maintain computerized tracking and date retrieval systems as part of the vessel traffic systems which are established pursuant to subsection (a), in all ports and harbors through which pass in excess of an average of one hundred thousand barrels per day of hazardous material carried in bulk as cargo.

Sec. 102(3) Establishing water or waterfront safety zones or other measures for limited, controlled, or conditional access and activity when necessary for the protection of any vessel, structure, waters, or shore area.

Sec. 4417a(4) Standard-setting authority gives Secretary authority to adopt vessel standards necessary for increased navigation and vessel safety and enhanced protection of the marine environment. Minimum standards would include, after January 1, 1979:

4417a(4)(B)(5)
- (A) a radar system with short- and long-range capabilities and with true-north features;
- (B) a Loran C, long-range navigation aid;
- (C) a transponder which can automatically report position and identification;
- (D) adequate communications equipment;
- (E) a fathometer;
- (F) two gyrocompasses;
- (G) up-to-date charts;
- (H) a segregated ballast system, if such vessel carries oil in bulk and is of a size in excess of twenty thousand deadweight tons;
- (I) a gas inerting system, if such vessel carries oil in bulk and is of a size in excess of fifty thousand deadweight tons; and
- (J) a redundant propulsion source.

Title III: Marine Safety Authority of the United States

A 200-mile zone, seaward of the territorial sea is established:
- within which discharge of oil or hazardous material would be prohibited;
- vessel traffic control regulations might be established;
- vessels destined for United States ports might be inspected.

Sec. 403 would establish a national inspection program and insure that each vessel covered under the Act was inspected at least once each year.

It is not clear how this Act would affect state coastal water management authorities; it is an issue that requires careful attention by coastal states.

CASE HISTORY: WASHINGTON STATE

The Alaskan pipeline was scheduled to begin transporting oil from Alaska's North Slope by the summer of 1977. It is estimated that as much as 2 million gallons of oil per day will flow to Valdez where the oil will be loaded on tankers and carried to the West Coast. This represents a tremendous increase in tanker traffic, which currently carried 6.3 million gallons of oil into this country daily.[7] Because of this projected increase, Alaska has continued to urge more stringent requirements under the Ports and Waterways Safety Act[8] and Washington State, where much of the oil is scheduled to be transported, has established regulations that restrict tanker size within Puget Sound to 125,000 DWT. The Washington Act also requires that above 50,000 DWT a tanker must have:

- aboard a licensed Washington State pilot;
- specific horsepower;
- twin screws;
- double bottom; and
- two radars, including avoidance radar.

As described in Chapter 4, the Atlantic Richfield Company challenged this law in the courts, and on February 28, 1977, the U.S. Supreme Court agreed to review the case. Resolution of this case may clarify the nature of coastal state authority to regulate tanker traffic within its coastal waters.

CONCLUSIONS

The Coast Guard has considerable authority to regulate the operation and construction of tankers. However, in an effort to secure necessary control over tanker traffic, Congress may inadvertently begin to diminish the authority or management capabilities of local port authorities and state coastal zone management programs. The consistency provisions of the CZMA should assure some degree of state input into Coast Guard planning and management. But complex surface control systems such as those suggested in H.R. 3796 may in fact become the coastal water management programs for a significant portion of a state's coastal zone. The legality and impact of such federal water control systems is unclear. But at a minimum it would seem provident to require that such systems be designed and implemented on a state-federal partnership basis. Full state and local participation in all phases of the system development might be required if such water use management systems are to have any hope of being consistent with state coastal management plans. Such systems will affect regional patterns of shore and water use, and cannot just be "plugged in" to a comprehensive state management program through a reactive consistency review.

REFERENCES

1. United States Coast Guard. "Navigation Safety and Vessel Inspection Regulations," *Federal Register* (January 31, 1977).
2. Testimony of William T. Coleman, former Secretary of Transportation, before Senate Commerce Committee, January 1977 as reported in *Conservation Report* (January 21, 1977), National Wildlife Federation, Washington, D.C.
3. Department of Transportation. Final Environmental Impact/4 Statement, Loop Deepwater Port License Application, Executive Summary (1976) p. 4.
4. Mostert, Noel. *Supership.* (New York: Alfred A. Knopf, 1974).
5. Office of Technology Assessment. *Oil Transportation by Tanker,* Washington, D.C. (July 1975) p. 19.
6. Siler, Admiral Owen, U.S. Coast Guard. *Conservation Report* (January 21, 1977) p. 22.
7. Kifner, J. "Flag-of-Convenience Oil Tankers," *New York Times* (February 13, 1977).
8. *Conservation News* (January 21, 1977) p. 22.

SOURCE: COASTAL WATERS: A MANAGEMENT ANALYSIS. JOHN M. ARMSTRONG AND PETER C. RYNER. ANN ARBOR SCIENCE. MICHIGAN: ANN ARBOR.

Annotated Bibliography

Report by the Maritime Transportation Research Board, Commission on Sociotechnical Systems, National Research Council. Port Development in the United States. Washington, D.C.: National Academcy of Science. 1976.

This report discusses and reviews the historical position of the port in the development of US trade. The emphasis is on major issues which have evolved from current trends, the present commercial functions of the ports examined relative to the major internal variables (labor, the types of commodities), external forces (trade patterns, changing ship designs, the competitive forces of transportation in the hinterland), and the future challenges which refulst from influencing forces of port development.

Some of the specific topics analyzed in detail include: containerization, the influence of the railroad, port labor, tankers, dry bulk transportation, and the forms of unitized cargo ships.

Port ownership, economics, planning and changes are all reviewed. The environmental effects and the evaluation of ecological impacts are presented. A segment of this report includes the evaluation of the data collected, various types of trade routes, the procedures of diverse trade routes, the procedures of numerous government bureaus and agencies, and an analysis of a wide variety of issues effecting port development. This includes federally financed programs to environmental and economic issues. A section on port planning and the evaluation of specific considerations preceeds the recommendations.

This report is rather detailed. Certain segments may be adapted for high school classroom use, or for independent study by selected students.

Hershman, Marc, et.al. Under New Management: Port Growth and Emerging Coastal Management Programs. Seattle: University of Washington Press. 1978.

This book is both a study and a report of Port Development and trends. Some problems of land and water use policies and conflicts as well as a concise review of Coastal Zone Management programs are included. Recommendations and conclusions are presented and eight specific case studies involving the East, Gulf, and West Coasts and the Great Lakes are presented in detail.

Annotated Bibliography

Ports

There are a few pictures and a variety of charts, maps, and graphs. There are many subdivisions of the materials within each chapter. This may be considered as good background material for the teachers and may even by used selectively with students.

Maritime Administration. *National Port Assessment: 1980-1990: An Analysis of Future United States Port Requirements.* Washington, D.C.: U.S. Department of Commerce - Office of Port and Intermodal Development. June 1980.

This study reviews the capacity of the Nation's ports and marine terminal facilities to meet the projected requirements of the US domestic and foreign water borne traffic over the next 10 years. This report has been summarized from considerable data, gathered over the past five years by the Maritime Administration in conjunction with the cooperative efforts of port planning studies in many States.

There is a summary of the findings, including: a review of existing facilities, financial cost data, future facilities needs, future capital requirements, and shipping technology. There is even a short section on inland riverports and terminals.

There is an excellent glossary of port related terms. This report is also recommended for independent study by selected students.

Final Report No. DOT TST 77 - 41. *Federal Port Policy In the United States.* University Research Contract No. DOT OS - 40004. Springfield, Virginia: National Technical Information Service. June 1977.

The policy governing ports in the US has traditionally evolved through the competitive relationship among ports. However, the vast changes in technology and other factors, especially environmental regulations, have changed this pattern. At present the Federal Government has a direct involvement regarding ports in three specific areas: a.) funds for the dredging and for port facilities, b.) the implementation of federal regulations as they pertain to the siting and operation of terminal facilities and vessel movements, c.) the formulation of new policies or facilities which directly or indirectly affect ports.

Annotated Bibliography

Ports

The current dilemma of the Federal port policy is the impact of Federal activities and regulations in the port area which historically was within the realm of the competitive port practices through the years.

This extensive review begins with the traditional and historical port procedures and practices within the USA. It analyzes the impact of modern technologies (international container service since the first major terminal in 1966, the advent of the super ships - over 200,000 dwt, tanker service,etc)and the respective impacts, both on shore and underwater of these and other changes in terminal areas. Coupled with these changes are the numerous demands of environmental awareness on a national level that directly affect US ports. This is especially true regarding the regulations for the disposal of dredged spoils, the various new regulations and activities of the United States Coast Guard, and other environmental agencies. All of these latter changes do have a direct and often immediate economic impact on ports.

The fragmentation of power due in part to a lack of port policy is discussed. There is also a review of the status and function of the States in the establishment of port policy.

Finally recommendations are made in relationship to the traditional competitive relationship among ports. This report is divided into segments with a concise historic review of the activities of the major Federal Agencies including: the Environmental Protection Agency, the Council on Environmental Quality, the U.S. Army Corps of Engineers, the Maritime Administration, The U.S. Coast Guard, The Department of Tranpsortation, and an"Analysis of Key Elements of the Institutional Process of Port Development". A variety of Appendices are included.

This material is not intensely technical. With clearly specified research directions, teacher discretion can be used in the assigment of specific areas to selected students. There are a number of graphs, charts, and tables that will also provide excellent source material.

Annotated Bibliography

Ports

The Appendices include the specific legislation as well as the statutory authority and/or agency for the implementation of this legislation.

National Resources Defense Council, Inc. Who's Minding the Shore? A Citizens' Guide to Coastal Management. Washington, D.C.: U.S. Department of Commerce, the National Oceanic and Atmospheric Administration, Office of Coastal Zone Management. August 1976.

This is an excellent and most readable booklet which is hopefully still in print and available. This could provide an excellent background and introduction for an understanding of the coastal zone and various land use patterns. The chapters are short and well written for the high school student.

Some controversial issues, for example, the siting of power plants are presented with a review of the major pro/con considerations. These are followed by recommendations. There is also a chapter on Coastal Property Rights which reviews land ownership and rights and also discusses various aspects of public interests. The right of private land ownership, so basic to America, is presented with a broad discussion of the rights of the individual to land ownership and this relationship to public land use. This booklet is recommended for student use.

New England Fisheries/Aquaculture

Fisheries

It has been estimated that whithin the 200 mile exclusive economic zone area of the United States, between wo and wo billion pounds of fish ean be yielded annually on a sustained basis within these coastal waters. Although the quality and species of this catch vary greatly, this represents a tremendous economic factor in the USA including the employment of fishermen, shipbuilders, chandleriers, fish processing plants, and various other infra industries.

Although the US fishing industry predates the establishment of the USA as a Nation, this industry has undergone some dramatic changes. Within the past decade, none have been as dramatic as the impacts from the passage of the Fishery Conservation and Management Act (FCMA of 1976) which came into effect on March 1, 1977. This law not only established eight regional councils for the conservation and management of the US fisheries industry, but also included specific regulations of the foreign distant water fleets whose fish catch in the early '70's surpassed the US catch, within the same US coastal waters.

Fish consumption is not as high in the US as in other areas of the world, but the rate of US consumption is increasing. Not only does the US have one of the largest coastal areas of the world, it is further blessed with some of the most prolific spawning and fisheries grounds in the world. This is particularly true of the Georges Bank area. Fisheries is a large US industry with an impact on a large economic portion of our nation. The FCMA has provisions which may encourage the development and even the expansion of the US fishing fleet. When the total allowable catch (TAC) has been determined for each species, the American fishermen are allotted the first opportunity to realize this TAC. Should there be any species whose catch does not total this amount due to the capacity of the US fleet, the foreign distant water fleets may be awarded a specific amount based on a permitting process. Since 1977 when the FCMA went into effect, there has already been an expansion of the East Coast fishing fleet, specifically the scallop fleet. This has added other complex problems to the fisheries industry.

The Student Activities in this section are designed to provide current information on the status of the US fishing and processing industries.

Aquaculture

Although Aquaculture has been efficiently practiced in many Asian countries for centuries, this is a rather new industry for the USA. The readings will give some background information and explanation of the importance and significance of Aquaculture in today's world. Many look with hope toward the potential that aquaculture has of providing great amounts of protein to the world's hungry masses.

The Student Activities are designed for a review of the existing Aquaculture capacities/potentials in the New England area. There are also readings on the Aquaculture pratices of other areas of the world, particularly, China.

CHAPTER 5

FISHERIES MANAGEMENT

Principal Agencies:	National Marine Fishery Service (NOAA) U.S. Fish and Wildlife Service (Interior)
Principal Legislation:	Fishery Conservation and Management Act of 1976 Fish and Wildlife Coordination Act Anadromous Fish Conservation Act Commercial Fisheries Research and Development Act of 1964 Marine Mammal Protection Act of 1972

Fisheries and fish stock management have a key role in coastal water use management considerations. Today the United States Consumes some 7 billion pounds (round weight) of fish.[1] This represents a 50% growth in consumption since 1960, and it has been estimated that consumer demand may increase by as much as 2.3 billion pounds (round weight) by 1985[2] leading to an annual consumption level of 9.3 billion pounds. Yet during this period of growing demand for fish products, the United States domestic commercial fishing industry, with the exception of the shrimp, tuna, king crab, salmon and menhaden fleets, has generally remained undeveloped or has deteriorated. Processors have been forced to rely more and more on imports to meet demand.[3]

It is estimated that U.S. coastal waters (within 200 miles) can yield between 20 and 40 billion pounds annually on a sustained basis.[4] But today these waters face a number of pressures, which endanger not only this estimated level of sustained yield, but also threaten the survival of some fish species. For example, while U.S. domestic landings have generally remained at under 5 billion pounds per year (4.7 billion pounds in 1973), the catch of foreign fleets within U.S. coastal waters (including 200-mile zone) has expanded to the point where the foreign catch reached an annual level of 7.9 billion pounds in 1972.[5]

At the present time, there is interest in the establishment of a comprehensive national fisheries management program. Several congressional studies led to the passage of the Fishery Conservation and Management Act of 1976, which created eight regional councils to develop comprehensive fisheries management plans (further description follows). Furthermore, Section 16 of the Coastal Zone Management Act Amendments of 1976 (PL 94-370) required the Secretary of Commerce to undertake a comprehensive review of the molluscan shellfish industry and to present a report to Congress by April 30, 1977. In 1976, the Department of Commerce published *A Marine Fisheries Program for the Nation*, which advocates a six-point national program for fisheries conservation and improvement.

Much attention has been given to the new fishery conservation zone (extended jurisdiction) that went into effect on March 1, 1977. There is considerable hope that this mechanism for controlling foreign fishing pressures within 200 miles of United States shores will protect declining commercial stocks and strengthen the domestic fishing industry. The planning for this zone, under the Fishery Conservation and Management Act of 1976, may represent the first comprehensive national fishery program.

If there is movement towards a national fishery management program, each coastal state is still challenged with major tasks and opportunities within its coastal waters. Much of the prime habitat areas, as well as many of the shore and water activities that can or do conflict with fisheries, are located within the territorial sea.

Control of foreign fishing vessels and the establishment of fishery quotas to insure sustained yield harvesting will be of little long-range value if the quality of coastal waters deteriorates to the point where a healthy fishery cannot be supported. In recent years there has been strong evidence that the living resources of coastal waters are seriously endangered.

PROBLEMS OF POLLUTION

Coastal fisheries are in serious difficulty. This is a result not only of excessive fishing pressures, but also because the coastal waters upon which the fish resources are dependent have in recent years become contaminated with a variety of toxic substances. These substances have either directly killed or damaged the fish stocks, or made finfish and shellfish unfit for human consumption.

In May of 1971, the Food and Drug Administration advised the public to stop eating swordfish, because more than 90% of its samples showed a mercury content of more than 0.5 parts per million (ppm). Although that action by the FDA remains a matter of controversy,[6] it was just the first in a series of pollution-related incidents. A listing of some of these occurences during 1976 and early 1977 indicates the seriousness and complexity of protecting living resources in coastal waters.

1. In 1976, the New York State Department of Environmental Conservation discovered high levels of Mirex and PCBs in Lake Ontario. In September of 1976, the state warned Lake Ontario fishermen not to eat salmon, lake trout, brown bullheads, catfish, smallmouth bass or eels. State plans to construct a new $10 million salmon and trout hatchery generated considerable controversy when it became clear that the fish would become contaminated upon release.[7] Similar findings of fish contamination, as well as controversy over increased fish plantings, occurred in Michigan where fishermen were advised not to eat salmon more than once a week. The director of the Department of Natural Resources decided not to expand the salmon program as had been proposed.

2. On January 14, 1977, the National Sea Clammers Association filed a $250 million class-action suit in federal court on behalf of clammers, lobstermen and fishermen charging that various officials of New York City, New York State, the state of New Jersey, the Army Corps of Engineers and the Environmental Protection Agency were negligent in allowing the pollution of a large area of Atlantic coastal waters which resulted in the loss of living resources.[8] The suit was based upon occurrences during the summer and fall of 1976 off the north shore

of New Jersey, where there were two major fish kills, causing mortality rates as high as 50%. An algae bloom and anoxic (oxygen depletion) conditions destroyed an estimated $14-16 million worth of finfish stocks and up to $22.5 million of shellfish.[9] Of particular concern was the possibility that the $50 million surf clam industry may have received long-range damage since one of the major kills took place during July, which is the normal spawning season for surf clams. It is not clear what contribution sewage sludge disposal had upon these kills. However, the evidence is compelling that this important section of Atlantic coastal waters is increasingly unable to sustain finfish or shellfish.

3. On November 16, 1976, a class-action suit representing some 10,000 persons including crabbers, clammers, shell fishermen, oyster tongers, seafood wholesalers, boat and restaurant owners was filed against the Allied Chemical Corporation for some $8.8 billion in damages resulting from the contamination in 1975 of the James River with Kepone by a plant under contract to Allied.[10]

4. Studies of oysters, clams and mussels in coastal waters of Washington, Oregon, Virginia, Delaware, Maryland, Connecticut, Rhode Island, Massachusetts and Maine revealed the presence of significant numbers of neoplasms (tumors). While these tumors may not preclude human consumption, they may indicate a rise in coastal water pollution. One of the researchers involved in the studies observed that while a decade ago only a few cases of unusual growth in shellfish were reported, in recent years they have been counted in large numbers.[11]

5. In January of 1977, the New York State Department of Environmental Conservation began to advise residents on the north shore of Long Island not to eat striped bass or large bluefish more than once a week, due to elevated PCB levels. It was emphasized that residents who had just one meal a week of bluefish or bass were "perfectly safe."[12]

6. On December 18, 1976, a coalition of fishermen filed a $60 million class-action suit against the Thebes Shipping Company, owners of the oil tanker *Argo Merchant*. Earlier that week this tanker broke in two on a Nantucket shoal and in the worst

oil spill in the nation's history[13] spilled some 7 million gallons of Number 6 "Bunker C" fuel oil into the Atlantic Ocean.

A further threat to fisheries management is the continued destruction of specific habitat areas such as reefs and estuaries, both of which are vital for feeding or breeding grounds. Dredging and filling has led to the loss of an estimated 4% of the nation's coastal habitat areas between 1950 and 1969.[14] As the need for dredge spoil disposal sites continues or increases, combined with a growing interest in the extraction of offshore deposits of sand and gravel, it is expected that coastal water habitats will become further endangered.

In attempting to integrate a comprehensive living resource management program into their coastal waters planning efforts, the states face a difficult task. Perhaps the greatest difficulty involved is that demand for the use of coastal waters for a wide variety of human activities is expected to intensify. These water uses have and will impart changes (both physical and chemical) upon the coastal water environment. Yet most finfish and shellfish have a limited ability to survive such changes. Their survival is primarily dependent upon genetically based biological limitations which are not always amenable to human multiple-use management schemes based upon other criteria.

CASE HISTORIES

There are several recent examples of fisheries disputes or problems that collectively reflect the scope of the coastal water management task. It is a task that involves not only complex natural systems, but also difficult problems of human conflict.

Jeffreys Ledge, Maine

Jeffreys Ledge is a fertile fishing ground off the coast of southern Maine which is frequented by both gill-netters and draggermen. Disputes have arisen between the two types of fishing, since on occasion gill nets have been damaged or destroyed by the draggers. This situation has been complicated by the fact that gill-netters fishing Jeffreys Ledge tend to reside in Maine, and draggermen fish out of Gloucester, Massachusetts.

The conflicts developed to the point where the situation was referred to by some as "the Battle of Jeffreys Ledge."

Resolution: At least for the present this conflict appears to have been reduced, if not resolved. The two groups of fishermen have met, along with observers from various state, regional and federal agencies, to discuss a fisheries management plan for the Jeffreys Ledge area. The plan, primarily an informal set of agreements between the two groups, includes the use of mutual radio channels, the preparation and distribution of charts showing where gill nets are deployed, and the establishment of a formal mediation arrangement.[15]

Savannah River Shrimp Grounds

The border between the states of Sourth Carolina and Georgia includes the Savannah River system, as defined by the Treaty of Beaufort in the 18th century. Because the actual location of the Savannah River has fluctuated over time, both Georgia and South Carolina claim jurisdiction over a 300-square-mile ocean area.

To a considerable extent, the issue is not that of shrimp harvesting but of jurisdiction. Specifically, the issue concerns which state has the authority to control fishing in a particular coastal water area. South Carolina allows shrimping to start in late May, while Georgia does not open its season until June. If the coastal waters in question are under Georgia's jurisdiction, the South Carolina shrimpers are violating Georgia law and their boats may be confiscated. If South Carolina controls the area, then Georgia's management plan is voided by the early fishing allowed under South Carolina regulations.

Resolution: This type of dispute tends to have long historic roots, and may take some time to resolve. However, it should serve as a signal to some states to give detailed consideration to the establishment of precise descriptions of its coastal water boundaries, including not only those between it and other states, but also at the state-federal interface at the three-mile limit. In some instances, state boundaries other than the landward ones are somewhat imprecise for their coastal zone. With increased use, conflicts and opportunities, the question of which set of

regulations will apply may be critical, and as some states have already learned, a matter of feet and inches can have significant and long-range implications. The advantages of establishing precise boundaries, taking whatever actions are necessary prior to expanded development, cannot be overemphasized.[16]

California Anchovy Fishery

The California Anchovy Fishery is under considerable fishing pressure. The anchovy is used by sport fishermen for gamefish bait and is taken by commercial seiners for sale to reduction plants where the fish are converted into fish oils, fertilizers and protein for chicken feed. California fishermen, both commercial seiners and sports fishermen, compete with commercial boats out of Mexican waters. A new $15 million reduction plant and fishing fleet in Ensenada, Mexico, is expected to further increase this pressure.

The California Fish and Game Commission supported by the California Department of Fish and Game, regulates this fishery. In 1976, their regulations included the designation of a fishing season, which was August 1-May 15 for a northern area and September 15-May 15 for the southern management area. Quotas were set at 100,000 tons of anchovies for the southern management area and 15,000 tons for the northern management area.

The issues facing the California Fish and Game Commission involve determining how much harvesting the anchovy fishery can support on a sustained yield basis and how the allowable catch should be allocated between the two interest groups. Commercial seiners desire larger quotas, claiming that if California commercial seiners do not harvest the fish, they will be caught by Mexican fishermen, since the fishery extends beyond California's coastal waters. Sports fishermen claim that anchovies are a critical bait species, and that necessary forage for game fish populations will be depleted if commercial seining continues. They further claim that the current reduction in anchovy stocks is a result of excessive commercial harvesting.

Resolution: Until such time as marine biologiest can establish the cause of anchovy stock decline, and of sustainable yields, the merits of either claim are unclear. The Fishery Conservation and Management Act of 1976 calls for the protection and improvement of both commercial and recreational fishing. Yet these two fishing interests may not always be compatible, just as various forms of commercial fishing may conflict. Through a formal coastal zone management mechanism, more interactions between land and water uses and between different coastal water activities can be accommodated within a given time and space. Yet the biological carrying capacity of a particular coastal water system may be relatively fixed and is, in many instances, being diminished by the introduction of pollutants. In some instances, expanded or protected fisheries may only be possible if other activities are excluded from coastal waters, or if the fisheries are managed so as to serve a primary user group, rather than attempting to provide multiple use.

Virginia Menhaden Fishery

The state of Virginia has established regulations over fishing activities in its half of Chesapeake Bay which include provisions that prohibit non-U.S. citizens from fishing within the three-mile limit of coastal waters and, of equal importance, also prohibits nonresident commercial fishermen from its coastal waters.

As described in Chapter 2, the Submerged Lands Act appears to give full title over submerged lands and "natural resources within such lands and waters" within the territorial sea to the states. However, as the discussion of basic federal authority attempted to convey, there are several federal powers, such as those for interstate commerce, that can preempt or constrain a state action even under the authority granted by the Constitution, the courts or Congress.

Seacoast Products, Inc. of Port Monmouth, New Jersey, has taken the state of Virginia to court over the regulations, attempting to have them overturned. A three-judge federal court decided that the regulation of aliens was a power reserved to the federal government by the Constitution, and that the laws are unconstitutional.

Resolution: The case arose from competition over menhaden stocks in the Atlantic Ocean and Chesapeake Bay. Several states have fishing residency laws as one method of regulating access to coastal fisheries. These are being challenged as nonresidents attempt to use finite coastal resources. A connected issue is that of beach access. Many communities prohibit nonresident use of certain coastal beaches or charge a special fee not applied to residents.

Because of the importance of this case to the authority of states to regulate their coastal fisheries, Virginia was supported by Maine, Maryland, Massachusetts, New York and Delaware in asking the U.S. Supreme Court to review the case. On May 23, 1977, the Supreme Court ruled that the Virginia laws are invalid insofar as they exclude nonresidents. The extent to which this decision will limit future state efforts at regulation of coastal fisheries is not yet clear. However, it emphasizes the complexities of coastal waters management and the degree to which a variety of federal laws and policies must be considered in any state management effort.

THE PROBLEMS OF MANAGEMENT

There are several problems of fisheries management that will affect most coastal water management programs.

Shore Facilities

In many coastal areas, industrial and residential development has either precluded or begun to conflict with commercial and recreational fishing activities. If the objectives of the Fishery Conservation Act and other federal programs are met, there will be a significant growth in domestic commercial fishing, as well as in aquaculture and recreational fishing. There will be a need for more boat and fish processing facilities; yet these facilities must compete economically, aesthetically and politically with a growing list of other activities that also use shore and water resources. In many communities, traditional patterns of land use are changing, and new zoning may preclude storage of equipment or other activities associated with commercial fishing. New OCS developments will require shore support facilities, including harbor space for service vessels, and these new interests may displace commercial fishing. If market economics becomes the sole method of coastal access allocation, commercial fishing could be in serious trouble.

Pollution from Fish Processing

The Environmental Protection Agency has estimated that 38% of all fish processing plants will have to be exempted from federal water quality requirements if they are to remain open, and that even with such exemptions, 16% will be forced to close. In the fall of 1976, seven sardine plants were fined by the Maine Department of Environmental Protection when they failed to meet an October 1 deadline for the installation and proper operation of water pollution control equipment.[17] As activities such as shore-based recreation and coastal residential development expand, several traditional water-based activities such as fishing and fish processing will require additional attention if they are not to be displaced by competing uses and more stringent standards. Special shore and water areas may have to be set aside for commercial fishing and related facilities. Otherwise they may not be compatible with other coastal uses, due to smell or other activity characteristics. The idea of special seafood processing parks, such as that now being considered for the Beaufort, South Carolina, area[18] may be of increasing importance.

As discussed in Chapter 1, coastal waters present some different management problems (and opportunities) than coastal lands. Fisheries management represents a prime example of this. Due to the nature of the water environment, the entire territorial sea, as well as any activity that affects them, is of concern to fisheries management. It is difficult, if not impossible, to isolate activities and their impacts to the degree that can be done on land. This may necessitate greater use of management devices such as exclusive-use zones, and may ultimately require some exclusion of types or amounts of activities from entire coastal water regimes to properly protect and enhance priority water uses.

Chlorine

Chlorine is used to "treat" human sewage, and to clean heat exchangers in power plants. More than 5000 tons of this chemical are released into coastal and inland waters each year.[19]

Federal standards tend to encourage heavy use of chlorine in sewage treatment, and some communities add extra amounts to provide a residue of "free" chlorine for added protection. Virginia, for example, requires that its effluent must have 2 ppm of free chlorine to protect its shellfish industry from contamination by viruses such as polio and hepatitis.[20]

However, both shellfish and finfish are very sensitive to chlorine. Oyster larvae, supposedly protected by extra amounts of free chlorine, die when exposed to chlorine levels nearly a thousand times lower than 2 ppm.[20] In terms of finfish and shellfish management, chlorine can be seen as a toxic pollutant. But the problem is even more complicated. In some instances chlorine reacts with the organic compounds in sewage, forming chlorinated hydrocarbons that may be as dangerous as PCBs. It has also been discovered that once discharged into coastal waters, chlorine can be displaced by bromine, thus forming brominated hydrocarbons related to chemicals such as PBB. As one research scientist has said: "That's good, hard evidence that we don't know what we're doing."[21] If present techniques of secondary treatment of sewage continue, and if flush water from power plants continues to be discharged into coastal and estuarine waters, large areas of coastal waters could be rendered unfit for living resources.

Conflicts Among Fishing Groups

Marine recreational fishing, which includes the harvesting of shellfish as well as finfish for personal use, has become a major coastal water use activity in the United States. Recent surveys estimate that there are almost 30 million marine recreational fishermen, and this number may increase by as much as an additional 15 million by 1985.[22] This creates an expanded demand for shore access and water surface use. It also represents a growing potential for conflict between recreational and commercial harvesting of finite fishery stocks. This type of conflict is further complicated by regional disagreements between different commercial fishing interests, including several important instances in which the courts have upheld historic fishing rights for native Americans. In some instances these decisions have led to a court-ordered management system which excluded other U.S. citizens from fishing grounds during part or all of the fishing season.

Perhaps the best-known treaty rights case led to a decision in February of 1974 by U.S. District Court Judge George Boldt. In that decision Judge Boldt determined that due to historic fishing rights certain treaty Indians must be allowed to take or attempt to take 50% of all harvestable salmon in the state of Washington's salmon runs.[15] Since then there has been a growing number of clashes between fishermen and enforcement officers, including the shooting of one fisherman. Recently similar fishing rights were recognized in Michigan's Upper Peninsula.

As described earlier, there has been increasing conflict between commercial anchovy seiners and sport fishermen in California, the problem being that there may not be enough anchovies for both interest groups. In Michigan, a similar concern has led to the prohibition of the use of gill nets by commercial fishermen and the creation of water zones to protect certain stocks for recreational fishing.

At the present time, American commercial fishing represents a $1 billion industry, employing some 500,000 people directly or indirectly. Additionally, some 30 billion people enjoy marine fishing (including shellfish harvesting) as a recreational activity:

> "Our fisheries are one of the nation's—indeed the world's—greatest resources, and will become increasingly important as a source of food for man in the decades ahead. We cannot permit the depletion of our fishstocks and the destruction of fish habitats to continue. We must learn to manage this resource so that we may use it to the optimum now and so that future generations may be able to use it and draw even greater yields from it. *And we can and must do it in ways which are compatible with the nation's need to develop other valuable uses of the ocean.*"[23] (emphasis added)

Translating these objectives into a workable state coastal management program will obviously be difficult. It may soon be necessary for both state and federal management programs to determine how much of finite fish stocks should be used by which groups. To make such choices, new decision rules may have to be invented by the public. Such decisions have been

avoided by increasing access facilties or putting more money into fisheries management. These choices are difficult not only technically, but also politically.

Direct Conflict with Other Coastal Users

As more people attempt to use the coastal zone for an expanding number of activities, conflicts will increase in number and severity. As reflected in recent court actions cited earlier, people engaged in various aspects of the fishing industry are now attempting to influence shore- and water-use decisions so as to protect their perceived interests in clean waters, sufficient harbor and processing sites, and protection of nearshore and deepwater habitats. Since finfish and shellfish are extremely sensitive to habitat loss and changes in coastal water characteristics, virtually every coastal water use proposal is likely to be viewed by those in the fishing industry or recreational fishermen as a potential threat to their interests. If aquaculture, recreational fishing and commercial fisheries are improved and expanded, as intended by the passage of the Fishery Conservation Act of 1976, there will then be an increased need for careful siting of facilities; for water and shore zones to protect habitat and fish harvesting areas; and for frequent evaluation of the type and amount of activity that can occur with coastal waters in harmony with expanded fisheries. For example, the February 1977 issue of *National Fisherman* reports the strong opposition of Virginia oyster packers to a proposed 250,000 bbl/day oil refinery that would be constructed in Portsmouth, Virginia, and discharge into the Elizabeth River. The number of interest groups wishing to participate in a coastal management decision is likely to grow as coastal management plans are implemented, making allocative choices increasingly difficult and complex.

THE FISHERY CONSERVATION ACT OF 1976

In 1976, the United States established a 200-mile economic zone adjacent to its territorial waters. The basic intent of the Fishery Conservation Act, by which this zone was established, is to insure that commercial fish harvesting is limited to rates that the resource can support over time, and the American fishermen be given priority access to fisheries' resources along our coasts. It also establishes a mechanism for a new level of comprehensive fisheries management.

Aside from the 200-mile zone, in which foreign vessels can fish only with a federal permit, the major features of this Act are eight Regional Fishery Management Councils which the Act authorizes:

1. *New England Fishery Management Council:* consists of 17 voting members and includes the states of Maine, New Hampshire, Massachusetts, Rhode Island and Connecticut and has authority over the fisheries in the Atlantic Ocean seaward of those states.
2. *Mid-Atlantic Fishery Management Council:* consists of 19 voting members and includes the states of New York, New Jersey, Delaware, Pennsylvania, Maryland and Virginia, and has authority over the fisheries in the Atlantic Ocean seaward of those states.
3. *The South Atlantic Fishery Management Council:* consists of 13 voting members including the states of North Carolina, South Carolina, Georgia and Florida and has authority over the fisheries in the Atlantic Ocean seaward of those states.
4. *The Caribbean Fishery Management Council:* consists of 7 voting members including the Virgin Islands and the Commonwealth of Puerto Rico and has authority over the fisheries in the Caribbean Sea and Atlantic Ocean seaward of those stated.
5. *The Gulf of Mexico Fishery Management Council:* consists of 17 voting members including the states of Texas, Louisiana, Mississippi, Alabama and Florida, and has authority over the fisheries in the Gulf of Mexico seaward of those states.
6. *The Pacific Fishery Management Council:* consists of 13 voting members, including the states of California, Oregon, Washington and Idaho and has authority over the fisheries in the Pacific Ocean seaward of those states.
7. *The North Pacific Fishery Management Council:* consists of 11 voting members and includes the states of Alaska, Washington and Oregon and has authority over the fisheries in the Arctic Ocean, Bering Sea and Pacific Ocean seaward of Alaska.
8. *The Western Pacific Fishery Management Council:* consists of 11 voting members, and includes the state of Hawaii, American Samoa and Guam, and has authority over the fisheries in the Pacific Ocean seaward of such states.

These councils have authority to formulate management plans that will directly affect the fisheries of coastal states. New fishing patterns and domestic pressures, increased promotion of aquaculture and economic shifts may result from council actions.

STATE COASTAL MANAGEMENT PROGRAMS AND THE FISHERY COUNCILS

The Fishery Conservation Act contains several safeguards to insure that state authority to manage coastal fisheries is not diminished. The governors of the affected states appoint most of the members of the councils, and the state director of fisheries management is included as a voting member on the council. Furthermore, state plans can be adopted by the council and Section 306 specifies that state jurisdiction over coastal waters is not to be extended or diminished by the Act.

However, there is some basis for concern. Section 306(b) stipulates that the Secretary of Commerce can, under certain conditions, assume management responsibilities of a specific fishery within the boundaries of a state if and as long as a state's management program fails to meet the Secretary's approval.

Also of concern is the possibility that these new regional councils, in formulating regional fisheries management plans, will interfere with state coastal zone management efforts. Council plans for increased fisheries development could conflict with state coastal water management objectives of industrial development, or may generate shore access pressures inconsistent with a state plan. While the state is given a strong role in council activities, there is no assurance that these activities will be coordinated with coastal management efforts. In some instances fisheries management is a separate state function, and communication may not occur unless the state coastal management program sends an observer to council meetings and makes other efforts to clarify the process and goals of the coastal management program. Otherwise, state coastal managers might have to evoke the consistency clauses of the CZMA.

There are several positive aspects to the Fishery Conservation Act. For the first time, the state coastal management programs (CZMP) can interact with a cohesive federal ocean fishery management system. These regional councils have the potential to increase the ability of states to manage finfish and shellfish within coastal waters. Inventory and habitat protection efforts by the councils can augment state efforts, especially if they are coordinated. Regional fisheries management plans can join with state programs to privde a systems approach to each fishery, going beyond the limits of the territorial sea. With a proper interface between coastal management and the regional councils, provision of shore facilities, habitat protection and coordination with other types of coastal water activity can be achieved.

MANAGEMENT APPROACHES

Even with regional councils, coastal states face a number of fisheries management problems, including marine pollution, insufficient shore facilities and a limited fish population. Most states are now trying one or more techniques to keep fishing pressure within the limits of fish stock. Some of these techniques include:

1. *closed seasons or areas* in which fishing is prohibited when or where the stocks are most vulnerable. These are spatial or temporal exclusion zones;
2. *limits on size* of certain species, to insure that species reach a size or age where they can reproduce;
3. *vessel limitations*, such as size, tonnage, or automotive power restrictions, designed to reduce pressure on the stocks by imposing technological inefficiency;
4. *limited entry*, in which only a certain number of fishermen or a certain number of boats are allowed to harvest a particular species. Sometimes vessels are purchased from the state, both as compensation and to insure limited fishing pressure;
5. *gear restrictions* designed for the same purpose as vessel limitations, or to make harvesting more selective, for either a specific species or a certain age class; and
6. *limits on catch*, which result in closing a fishery once the total allowable catch has been reached.

The Coastal Zone Management Act allows states to augment such approaches with a comprehensive regulation of activities to insure that critical habitat, necessary shore facilities and required water quality continue to exist. By designating areas of particular concern, priorities of use, and permissible and nonpermissible uses in shore and water areas, the state coastal program can not only assure continued commercial and recreational fisheries, but also place them within the broader context of multiple resource use, balancing fisheries needs against other activities and other resource parameters.

A traditional state fishery program could not really hope to regulate water quality, surface water use, dredge spoil disposal, ocean dumping, estuarine fill and all the other factors that can endanger a continued fishery. But if living resources are to be protected and improved as part of a state CZMP, there are certain implications for program design that must be considered. Finfish and shellfish are highly reactive to most changes in the marine environment, especially thermal and chemical changes. They are interlinked in extraordinarily complex and sensitive biogeochemical webs that must be maintained. In many instances the concept of multiple use is difficult if not impossible to translate into allocative patterns compatible with fisheries management. In some instances a choice between a viable fishery or another set of uses may be required. Both may not be possible in the same environment. Spatial separation, which can work quite effectively in land use management, has less impact in coastal waters, where there is constant interchange through the aquatic medium. Since the demand for coastal water access for purposes other than fishing can be expected to grow, great care must be given to identifying conditions under which activities might be compatible, and priorities constantly reassessed.

OREGON

On January 1, 1977, a new set of statewide planning and management goals and guidelines went into effect for the state of Oregon. Adopted by the Land Conservation and Development Commission, these goals and guidelines indicate a clear understanding of the management needs of strong fisheries, and a choice to favor the management of living resources over other uses. This is a major choice, for from it flows the majority of priorities and permissible uses for the entire coastal zone. It is also a difficult choice, for Oregon, as well as all other coastal states, has a variety of needs beyond those of living resources management.

> *Goal 19: Ocean Resources*
>
> To conserve the long-term values, benefits, and natural resources of the nearshore ocean and the continental shelf.
>
> All local, state, and federal plans, policies, projects, and activities which affect the territorial sea shall be developed, managed, and conducted to maintain, and where appropriate, enhance and restore, the long-term benefits derived from the nearshore oceanic resources of Oregon.
>
> Since renewable ocean resources and uses, such as food production, water quality, navigation, recreation, and aesthetic enjoyment, will provide greater long-term benefits than will non-renewable resources, *such plans and activities shall give clear priority to the proper managment and protection of renewable resources.* (emphasis added)

CALIFORNIA COASTAL MANAGEMENT POLICY

The California Coastal Act (SB 1277) was established as law in 1976. It provides a strong policy statement regarding fisheries management and marine environmental protection.

> Section 30230:
>
> Marine resources shall be maintained, enhanced, and, where feasible, restored. Special protection shall be given to areas and species of special biological or economic significance. *Uses of the marine environment shall be carried out in a manner that will sustain the biological productivity of coastal waters and that will maintain healthy populations of all species of marine organisms adequate for long-term commercial, recreational, scientific, and education purposes.*

This policy statement, to the degree that it is adhered to and translated into coastal water allocative decisions, would have major impact upon all coastal water uses. In terms of management, it affords decision-makers a clear indication of how to choose among alternative patterns of coastal water use. It also

provides a strong, relatively clear measure by which the state of California can evaluate pending federal activities under the consistency provisions of the Coastal Zone Management Act of 1972. It is, in effect, a performance standard that all coastal water uses must observe and meet if they are to be permitted.

> Section 30234:
>
> Facilities serving the commercial fishing and recreational boating industries shall be protected and, where feasible, upgraded. Existing commercial fishing and recreational boating harbor space shall not be reduced unless the demand for those facilities no longer exists or adequate substitute space has been provided. Proposed recreational boating facilities shall, where feasible, be designed and located in such a fashion as not to interfere with the needs of the commercial fishing industry.

To assure a strong commercial fishing industry, at least two major conditions must be protected and improved. First, the quality of the water environment must be maintained in a state that can support healthy populations of fish. Section 30230 declares that it is the policy of the state of California to manage coastal water uses on the basis of such maintenance.

But a second condition, which is becoming very serious in many coastal areas, is to provide adequate shoreside facilities. Fishing harbors were once thought of as picturesque settings by tourists and summer residents. But increasingly, the necessary docks, net storage areas, bait storage bins, fueling facilities and processing plants may be seen by some as nuisance activities that conflict with recreational and residential use of shore and water areas. Zoning at the local level may increasingly preclude activities necessary for successful commercial fishing operations.

Also, anchorage and dock space is becoming more difficult to obtain, as affluent recreational boaters and offshore oil workboats compete for limited water access facilities. Given the trends and forecasts for a continued growth in demand for shore and water access by a wide variety of activities, it would seem that deliberate enclaves must be set aside for commercial fishing activities, if they are to continue.

Clearly, the choice to favor fishing as a priority use has major impacts, and represents perhaps the single most important allocative decision that a coastal water use management program can make. If it is to be a priority use, then the negative impacts of all other water activities must be controlled on the basis of fishery management objectives. However, there can be few other coastal water uses that are more important; have more historic claim to adequate consideration; and that are as totally dependent upon the maintenance of a high-quality marine environment and adequate shore facilities. Given the pressures for expanded development of the waters and submerged lands of the marine environment, maintenance of adequate conditions for commercial and recreational fishing represents perhaps the greatest challenge to any state coastal management program.

REFERENCES

1. United States Department of Commerce. *A Marine Fisheries Program for the Nation* (July 1976), p. 14.
2. *Ibid.*, p. 15.
3. *Ibid.*, p. 9.
4. *Ibid.*, p. 6.
5. *Ibid.*, p. 5.
6. "Florida's Swordfish Bonanza Choked by FDA" *National Fisherman* (December 1976), p. 9-A.
7. Severo, R. *New York Times* (January 14, 1977).
8. Sullivan, J. *New York Times* (January 14, 1977).
9. *National Fisherman* (February, 1977).
10. *New York Times* (November 16, 1976).
11. Webster, B. *New York Times* (January 27, 1977).
12. Pett, A. *The Port Washington News* (January 20, 1977).
13. Robb, C. *The Cape Codder* (December 23, 1976).
14. U.S. Department of Commerce. *A Marine Fisheries Program for the Nation* (July 1976), p. 8.
15. *National Fisherman* (December 1976).
16. *Ibid.*, (November 1976).
17. *Ibid.*, (December 1976).
18. *Ibid.*, (March 1977).
19. Jolley, R. Oak Ridge National Laboratory, cited in Lawrence Wright, "Troubled Waters," *New Times* (May 13, 1977), p. 43.
20. Wright, L. "Troubled Waters," *New Times* (May 13, 1977), p. 43.
21. Carpenter, J. Department of Chemical Oceanography, University of Miami, cited in Lawrence Wright, "Troubled Waters," *New Times* (May 13, 1977), p. 43.

22. U.S. Department of Commerce. *A Marine Fisheries Program for the Nation* (July 1976), p. 9.
23. *Ibid.*, p. 3.

RECOMMENDED READINGS

General Accounting Office. *The U.S. Fishing Industry: Present Condition and Future of Marine Fisheries*, Vols 1, 2. Comptroller General of the United States (December 1976).

National Fisherman. A monthly newspaper covering fisheries management throughout the United States. Subscription information available from *National Fisherman*, 21 Elm Street, Camden, Maine 04843.

National Marine Fisheries Service and Fish and Wildlife Service. *Living Coastal Resources*, Office of Coastal Management (July 1976).

United States Congress, Committee on Commerce. National Ocean Policy Study. *Legislative History of the Fishery Conservation and Management Act.* U.S. Government Printing Office (1976).

United States Congress, Committee on Commerce. National Ocean Policy Study. *Congress and the Oceans: Marine Affairs in the 94th Congress.* U.S. Government Printing Office (1977), pp. 3-54.

United States Department of Commerce. *A Marine Fisheries Program for the Nation* (July 1976).

SOURCE: COASTAL WATERS: A MANAGEMENT ANALYSIS. JOHN M. ARMSTRONG AND PETER C. RYNER. ANN ARBOR SCIENCE. MICHIGAN: ANN ARBOR.

FISHERY RESOURCES: FOOD FOR THE HUNGRY

In the last 25 years the world fish harvest has nearly quadrupled. The annual catch rests between 70 and 75 million metric tons, valued at nearly $10 billion. From 11 to 15% of the world's total protein supply comes from the sea, according to United Nations figures. Yet it has been estimated that the oceans produce over two billion tons of fish and shellfish each year, enough animal protein to keep ten times the world's population in good health. The harvest from presently harvested species could be nearly doubled, with the remainder of the increase coming from "unconventional" species such as squid and octopus. Yet since less than one percent of seafood comes from marine plants and very little from marine "herbivores"* at the lower end of the food chain, experts point out that there are limits to which the sea can be expected to feed world populations. This does not mean that there is not a vast potential increase to be had.

The importance of fish protein to national diets varies considerably. Generally speaking, developing countries' populations consume more than those in industrialized countries. Many small island nations are dependent on marine food supplies. The Japanese consume one-half of their animal protein in the form of seafood. The Soviets and the Scandinavian nations, including Iceland, which cited dependence on fishery resources in regard to its dispute with British fishermen, are exceptional industrial nations whose inhabitants eat a lot of seafood.

Atlantic Ocean

Total 1965 catch:	17,276
Total 1974 catch:	24,766.5
Potential catch:	53,700

Pacific Ocean

Total 1965 catch:	22,912
Total 1974 catch:	31,832.3
Potential catch:	55,500

Indian Ocean

Total 1965 catch:	1,874
Total 1974 catch:	3,021
Potential catch:	7,300

Mediterranean Sea

Total 1965 catch:	926
Total 1974 catch:	1,376.9
Potential catch:	1,700

(in thousand metric tons)

Southern Oceans

Experts estimate Antarctic krill at from 800 to 5,000 million tons with a 60 to 100 million annual ton harvest.

Source: *Actual catch figures taken from Food and Agriculture Organization Yearbook of Fishery Statistics, 1974, No. 38. Potential catch figures taken from Provisional Indicative World Plan for Agricultural Development, Chapter 6, vol. 1, Food and Agriculture Organization, 1970.*
NEPTUNE No. 9

A large part of the world's annual harvest of fish is caught not by the coastal states but by distant-water fishing countries.* About half of the fish caught within 200 miles of shore are recovered by foreign fishermen. The developed nations garner approximately half of their "foreign" catch off other developed nations' coasts, and less than one-half off developing nations' coasts. Since few developing nations possess distant-water fleets, they recover virtually no fish off developed nations' coasts, although they do cruise near fellow developing nation shores.

*herbivores- *plant-eating animals.*

*distant-water fishing nations- *Spain, Japan, the U.S.S.R., Poland, Portugal, South Korea, Thailand, Bulgaria, Romania, the U.S., and East and West Germany.*

- Japan takes up to 45% of its total catch within 200 miles of foreign states.

- The U.S. gets more than 80% of its catch by volume off U.S. shores, although these resources amount to less than 50% of the value of the entire U.S. harvest. Distant-water tuna, salmon, and shrimp operations accounted for 42% of the 1975 U.S. harvest.

- It has been estimated that 10% of the world's fishery resources lie off U.S. coasts.

- Foreign fishermen recover about 70% of coastal fishery resources off the U.S. (prior to enactment of the U.S. 200-mile Zone of Fishing Jurisdiction).

SEA MEADOWS LIE FALLOW

Major unutilized or underutilized fishery resources are:

- the oil sardine off Oman and southern Arabia up to Iran, estimated one million metric ton annual harvest;

- coastal stocks off India and in the Indian Ocean generally, from three million metric tons up to 12 million;

- South China Sea stocks;

- over Argentina's Patagonian shelf, where an estimated five million metric tons could be harvested annually;

- off Mauritania and possibly other areas of West Africa; and

- Antarctic krill -- small, shrimp-like creatures estimated at from 800 million to 5,000 million tons in the Southern Oceans, or from 60 to 100 million tons annual harvest.

Of the more than 20,000 species of ocean fish, only a few dozen are exploited. Species such as squid and octopus are eaten only in certain areas of the world, and several types of crab on the U.S. continental shelf and the jack mackeral could yield almost as much as the existing U.S. fish catch.

NO BENEFITS IN OVERFISHING, BUT IT CONTINUES

Since the world fishing effort has concentrated in the northern hemisphere, resources there have been severely depleted in recent years. Herring, haddock, menhaden, yellowtail flounder, halibut, Pacific mackeral, sablefish and shrimp off U.S. coasts have been affected.

The California sardine, a thriving industry from the 1930's to the 1950's, famed in Steinbeck's "cannery row," declined due both to overfishing and to climatic conditions. The Peruvian anchovy catch in 1973 substantially decreased for the same reasons.

Intense fishing hurts the capability of a species to reproduce by reducing the numbers of spawning fish. Technological advances and new fishing techniques have both contributed to over-fishing. Location of fish by sonar and helicopter, factory ships which permit fleets to remain at sea for long periods of time, fine mesh nets which recover both adult and immature fish before they have a chance to spawn, and the very mobility of the technologically-advanced fishing fleets lead this assault.

Source: *Elements of Marine Ecology*. *R.V. Tait and R.S. DeSanto. 1975, p. 224. Reproduced with permission of R.V. Tait.*

WORLD FISHING FLEET LARGE AND GROWING

The size of the world fishing fleet over 100 gross tons has been growing at an average annual rate of six percent and the tonnage by ten percent. The combined global fleet over 100 gross tons in mid-1973 was 17,000 units of some ten million gross tons, or 34% and 43% greater, respectively, than in 1961. The introduction of larger types of factory vessels seems to be slowing down, with a growth rate of six percent in 1973 as compared to an annual average growth rate of 16% over the previous four years.

A COSTLY WASTE

Fish harvesting, processing and marketing as practiced today have a negative impact on energy conservation and utilization of fishery resources as a source of food to feed the world's hungry. Modern distant-water fishing fleets consume large supplies of fuel oil. The severe rise in oil prices has forced many nations to subsidize fuel prices for their fleets. Factory ships weighing up to 44,000 tons often use up to one ton of fuel for each ton of usable fish produced. Long trips to the Antarctic to harvest Antarctic krill* will suffer from high fuel costs. One

*krill- *small, shrimp-like creatures.*

United Nations's fisheries expert claims that in the North Sea fisheries, twenty kilocalories* of fossil energy are consumed to produce one kilocalorie of gutted fish. The parallel ratio for vegetable protein production ranges from 1:1 up to 10:1, for beef rests at 10:1, and for lamb at 16:1. Dairy production requires a similar 20:1 ratio while feedlot beef or pork are higher.

In the harvesting of some species, the incidental catch* of other species is thrown back to the ocean depths. For every pound of shrimp taken in the Gulf of Mexico, a shrimp boat takes five to ten pounds of other kinds of fish; in a catch of 200 million pounds of shrimp, as much as two billion pounds of fish may be dumped overboard to make room for more shrimp. The Japanese fishing for pollack may reject 100 million edible tanner crabs because U.S. law prohibits foreigners from keeping continental shelf species such as crab unless authorized by treaty or agreement.

India, Malaysia, Thailand and Indonesia looked into possible ways of converting their trawler by-catch, or incidental catch, into food products. They must find a way to efficiently deal with limited ship capacity and equipment, the variability of quantities recovered, and how to process the pot luck species of different color, fat content, taste, etc.

Attractive packaging geared to industrial nation markets often places fishery products beyond the purchasing power of the local populace where the resource is harvested. Tailoring fish products for export markets brings mixed blessings. On the one hand, meeting the quality control standards of importing nations may raise local consumer standards and handling procedures in the country of origin. Better storage facilities and methods may be developed and wasteful spoilage diminished. On the other hand, striving to penetrate international markets may price fish products out of the range of local buyers. One Latin American fishery expert has outlined the problem in this manner: in the industrialized nations there is no real lack of adequate protein supply. Therefore different forms of protein compete in a market characterized by relatively high purchasing power. Competition in the form of presentation (frozen, canned, etc.), packaging, advertising, distribution and varied preparation recipes drives up the price of the basic product in markets in the country which initially caught the fish.

If local producers do not invest in different kinds of expensive and unnecessary fishing and fish processing technology, but turn instead to developing a simple, cheap product acceptable to regional and local consumer preferences, much of the fish harvest could go to feed the hungry and the poor.

While two-thirds of fish protein produced is directly consumed, one-third of the world's fish production today is made into fish oil and fish meal. Soybeans and fish meal are the two major sources of protein for livestock and poultry. It takes more than four pounds of grain on an overall average to grow one pound of beef, pork or turkey, or

*kilocalories- *kilogram calorie: the unit of heat equal to the amount of heat required to raise the temperature of 1 kilogram of water by 1 degree Centigrade at 1 atmosphere pressure.*

*incidental catch- *fish species taken on-board which are not those sought by the fishermen.*

two pounds of grain mixed with high protein fish and oilseed to produce one pound of chicken meat. Alternatively, approximately four and one-half pounds of fish converted to animal feed yields less than one-half pound of chicken.

A fisheries expert in the Inter-American Development Bank in Washington, D.C. estimates that by combining the annual Latin American anchovy harvest and the unutilized fishery resources off the continent, Latin Americans could make up their annual protein deficit. Peru and Chile are trying to orient their anchovy product toward fish protein concentrate for direct human consumption.

-Lee Kimball

OFFSHORE OIL AND GAS

PLENTIFUL...

Approximately 20% (or ten million barrels daily) of world petroleum production takes place in offshore areas today. Offshore natural gas fulfills six percent of world consumption needs. These percentages will increase dramatically by the year 2000. Offshore areas may supply five times as much oil, or by 1980, they may account for from 30 to 40 percent of the world total. In 1975, the U.S. produced 1.2 million barrels of offshore oil. The U.S. Federal Energy Administration (FEA) predicts that by 1985, "lower 48"* production will amount to 2.1 million barrels per day, and that Alaskan production on the outer continental shelf* will be at 0.8 million barrels per day. Thus U.S. offshore oil would account for 22% of U.S. domestic supplies in 1985.

*lower 48- *U.S. states on the continental mainland, excluding Alaska.*

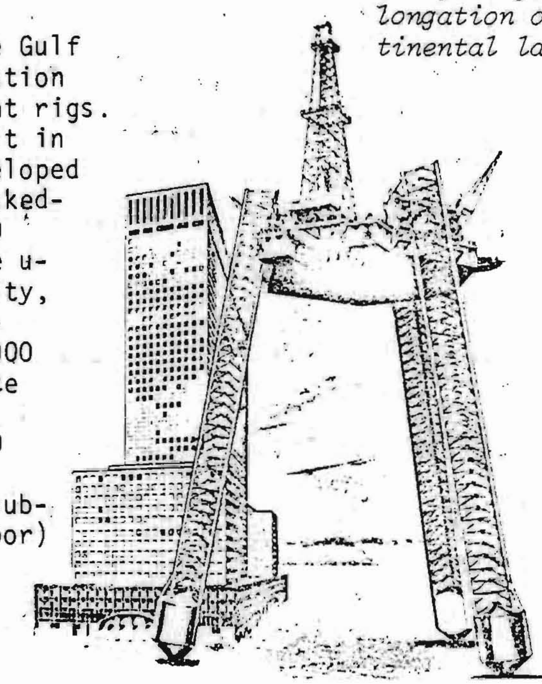
*continental shelf- *shallow portion of the continental land mass, usually cut off at the 200 meter depth mark.*

A United Nations study estimates that there are at least 170 billion barrels of proven offshore oil reserves and 2.3 trillion barrels of exploitable resources, enough to satisfy world consumption at present levels for 140 years. As stated earlier, experts think that the seabed contains over 30% of remaining world oil and gas.

The U.S. National Petroleum Council estimates that between 30 and 45% of world seabed oil lies beyond the continental shelf, that is, beyond the 200-meter depth mark, further out in the continental margin.* Also important to note is that ninety-four percent of offshore oil is located off non-U.S. shores.

*continental margin- *the geological prolongation of the continental land mass.*

Offshore oil exploitation began in 1947 in the Gulf of Mexico. It consists of two stages: exploration and production. These stages require different rigs. Exploration drilling platforms were first built in shallow waters until the jack-up unit was developed in 1952. This is a platform which can be "jacked-up" above the waves, although its limit is 300 feet of water. Subsequently, semi-submersible units were constructed with a 2,000 foot capacity, and drill ships which can be moored* or dynamically positioned* in deeper waters up to 3,000 feet. These are expected to be able to operate at any depth in the future. Production units are generally fixed platforms limited to 1,000 feet. Various other systems for deeper areas exist, but most oil companies are working on subsea production systems (resting on the sea floor) which could be used in 3,000 feet of water by 1980 and ultimately at any depth.



Source: *Our Nation and the Sea. Report of Commission on Marine Science, Engineering and Resources. 1969, p. 126. Government Printing Office.*

... BUT SHARED BY A FEW

Just as living resources and the ability to exploit them are unevenly distributed around the

*moored or dynamically positioned- *see next page.*

STUDY QUESTIONS

Marine Fisheries: Food for the Future?
by Richard C. Hennemuth

Briefly answer the following questions based on the article.

1. Discuss the estimated food potential within the oceans. Relate this to the human Recommended Daily Allowence.

2. What is the potential harvest of fish throughout the world? Where is it generally located?

3. Which countries are most responsible for the total marine catch?

4. The author cautions: "... man's continuing activities in the marine ecosystem means that maintaining its productivity and realizing the estimated potential requires considerable restraint to prevent adverse changes." What were some of the contingencies he explained?

5. Explain the two methods by which the productivity of living marine resources is generally determined.

6. What impacts are expected from technological and social developments in the next 25 years?

7. Explain some of the factors that were cited for reduced fishing yields.

8. In what sense is the Antartic krill considered a possible exception? Note some of the problems associated with the Antartic krill.

9. What conclusions are made in this article?

Marine Fisheries: Food for the Future?

by Richard C. Hennemuth

The oceans have been a mystery to us until recent times, a source not only of admiration and awe but of comforting speculation: anything so vast, the thinking has gone, must hold limitless resources for man to harvest. As populations grew and nutrition became a central world problem, governments asked marine scientists to estimate the food potential beneath the waves. Different techniques were used, the numbers meant different things, and the range of responses varied widely: the figures over the last 25 years have run from under 100 million tons to 2 billion tons of annual production, the larger number more than enough to satisfy the most anxious nutritionist. It has been calculated

School of cod fish on the Grand Banks. (Photo negative by Bell Telephone Lab/NMFS) that about 36 grams of protein per day per person is adequate for essential maintenance. Thus the average annual marine catch of 50 million metric tons in recent years could, if entirely directed to that end, supply 30 percent of the protein needed by the world's 4 billion people. By the year 2000, when most projections place the total population at 6 billion, the catch would have to rise to 100 million metric tons to meet the same need.

Over the last couple of decades, increased fishing effort, primarily by long-distance fleets of large vessels, generally has produced proportional increases in yields. The last six years, however, have seen a leveling off of total harvests despite increased fishing (Figure 1). No one knows whether the trend will continue or be reversed by improved technology. The uncertainty is reflected in today's estimates of yield by the year 2000. Some scientists say that even a doubling is not possible, while others predict harvests five times what they are now. Clearly, it would be useful to examine the bases for these varying projections, the uncertainties involved — including those generated by economic and social as well as purely scientific factors.

The Resource

The number of different categories of marine animals that could be harvested is in the tens of thousands. Most are rare or sparsely distributed or for other reasons do not appear on the tally; species actually caught number little more than a thousand. A case in point: off New England, there are about 200 species of fish of which 30 account for 95 percent of landings.

On a worldwide scale, the clupeoids or herring-like fish are the most ubiquitous. They provide the greatest catches of any group and include hundreds of species. Yet even here 10 species account for about 75 percent of the landings. Nine major groups of species provide about 80 percent of the total world catch of all marine animals and plants (Table 1). Almost all organisms tend to aggregate in concentrations, the densest of which provide the basis for today's successful fisheries. Even the species that do provide high yields, however, on the average are not very densely distributed. Adult demersal fish, those associated closely with the bottom, average about one individual per cubic meter. Pelagic fish also average about one per cubic meter. The adult fish range from 1/10 to 100 kilograms in size. Zooplankton, the small animals (weighing 0.01 grams or less) that drift in the water column, average about 100 individuals per cubic meter in the upper water column.

The largest part of the fishery resource is located on or above the continental shelf out to a water depth of 270 meters. The productivity of some of the richest areas is based on a variable habitat and

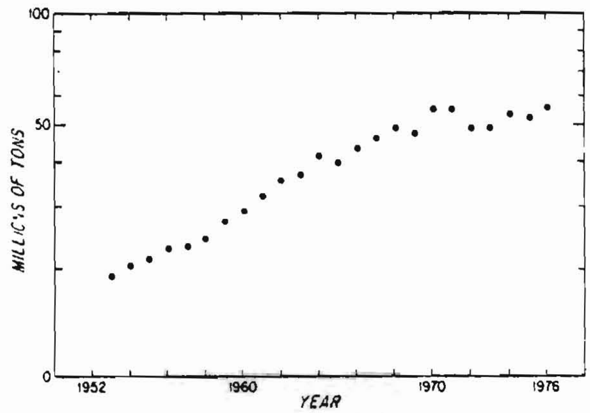


Figure 1. The world catch of marine fishes from 1952 through 1976. (Source: FAO)

a multi-species fauna. Yields of from 3.0 metric tons per square kilometer of surface area (Northeast Arctic Ocean, New England Shelf) to 5.0 (North Sea) have been obtained by intensive fisheries. Most of the shelf area is located well within 200 miles of the coastline, and is thus under control of the coastal nations because of recently accepted extended jurisdictions.

The largest share of the global marine catch (60 percent) comes from the temperate waters of the Northern Pacific and Atlantic Oceans. The catch from the central and southern zones follows in decreasing order (Table 2). The north temperate seas have large areas of particularly productive shelf, where correspondingly the fishing has been most intense. These areas border the more

Table 1. Leading species groups in world marine catches (in millions of metric tons).

Species	*1976*		*1970*	
Herring, sardines, anchovies	15.1		21.6	
Cod, hake, haddock	12.1		10.5	
Jacks, mullet, sauries (capelin)	7.4	(3.4)	4.1	(1.5)
Redfish, bass, congers	4.9		4.0	
Mackerel, cutlass fishes	3.3		3.1	
Tuna, bonita, billfish	2.2		2.0	
Shrimp, prawns	1.3		1.0	
Squid, octopus	1.2		0.9	
Flounder, halibut, sole	1.1		1.3	
	48.6		48.5	
All marine animals and plants	61.5			

industrialized countries, which have developed strong coastal and distant-water fleets.

The 10 leading fishing nations take about two-thirds of the total marine catch (Table 3). The top two, Japan and the Soviet Union, have the largest catches from non-home waters. The leaders have not changed much since 1970. The greatest changes have occurred in South Korea, which has more than doubled its catch since 1970, and in Denmark, which has increased its catch 150 percent. Twenty countries now harvest more than 1.0 million metric tons annually. Chile and Peru, notably, have depended on one species, the anchoveta; this fishery failed in 1972 (see *Oceanus*, Fall 1978, p. 40), and has not yet recovered. South Africa (pilchard and anchovy), and Norway (capelin) are more than 50 percent dependent on one main fishery. The remainder are rather well diversified. The overall distribution of catch shows that much of the harvest is taken in or near home waters. The long-distance fleets, however, have been important to many countries, both traditionally (Spain, Portugal) and in recent developments (Japan, the Soviet Union, Cuba, Poland, South Korea, to name a few).

In 1976 catches, the leading species group included herring, sardines, and anchovies (Table 4). Traditionally, this group had been at the top, but has dropped significantly in recent years, primarily because of the Peruvian anchovy problem, but also because of decreasing herring catches. The cod, hake, and haddock species group is a close second, and together the two groups account for about 40 percent of the total catch. The herring group in the past has been utilized to a large extent for fish meal and oil, but in the last few years has been used more often for direct human consumption. The cods are almost totally used for this purpose. The third group — jacks, mullet, and sauries — is the only one that has increased markedly since 1970, primarily because of the development of capelin fisheries in the North Atlantic, which were not heavily exploited prior to 1970. These species are used primarily for meal and oil products.

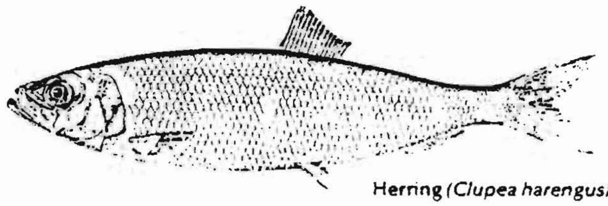
The total 1975 catch in United States continental shelf areas was about 5.8 million metric tons, the foreign catch representing about 3 million of it. Almost all the catch in the United States is taken on the continental shelf; most is consumed domestically. The United States imports about 60 percent of its food fish consumption and in this respect is unique in the world (Tables 5 and 6).

The Ecological Basis of Fisheries

The dynamic renewability of the living marine resources is crucial to their importance as a potential source of food. Sustained exploitation, of course, depends on that renewability. Yet that exploitation is based in large measure on concepts and assumptions having less than satisfactory

Table 2. Marine fisheries catch by area in 1975 (in millions of metric tons).

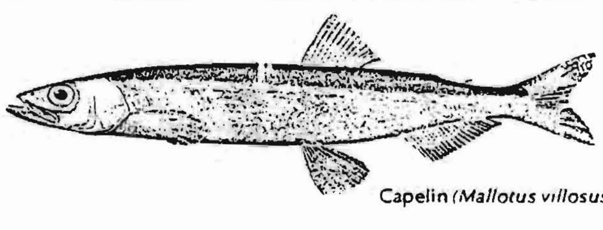
	Atlantic	Pacific	Total
North	15.9	19.3	35.2
Central	6.4	9.3	15.7
South	3.4	4.9	8.3
Total	25.7	33.5	59.2



Herring (*Clupea harengus*)

Table 3. Leading fishing countries in 1976 (in millions of metric tons).

Countries	*1976*	
Japan	10.6	
Soviet Union	10.1	
Peru	4.3	
Norway	3.4	
United States	3.0	
South Korea	2.4	
China (Mainland) and Taiwan	2.3	(4.5 freshwater)
Denmark	1.9	
Thailand	1.6	
India	1.5	(0.9 freshwater)

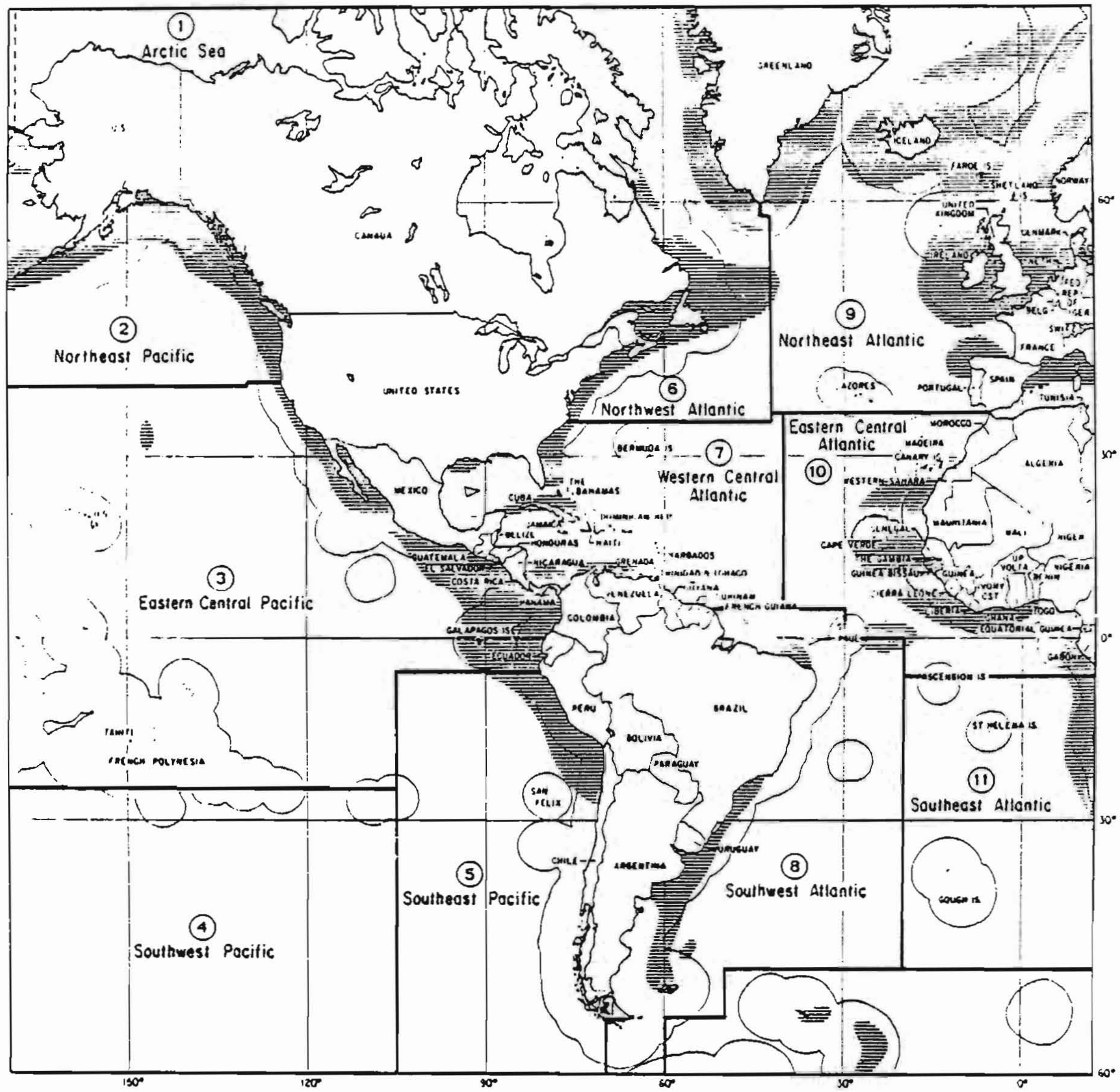


Capelin (*Mallotus villosus*)

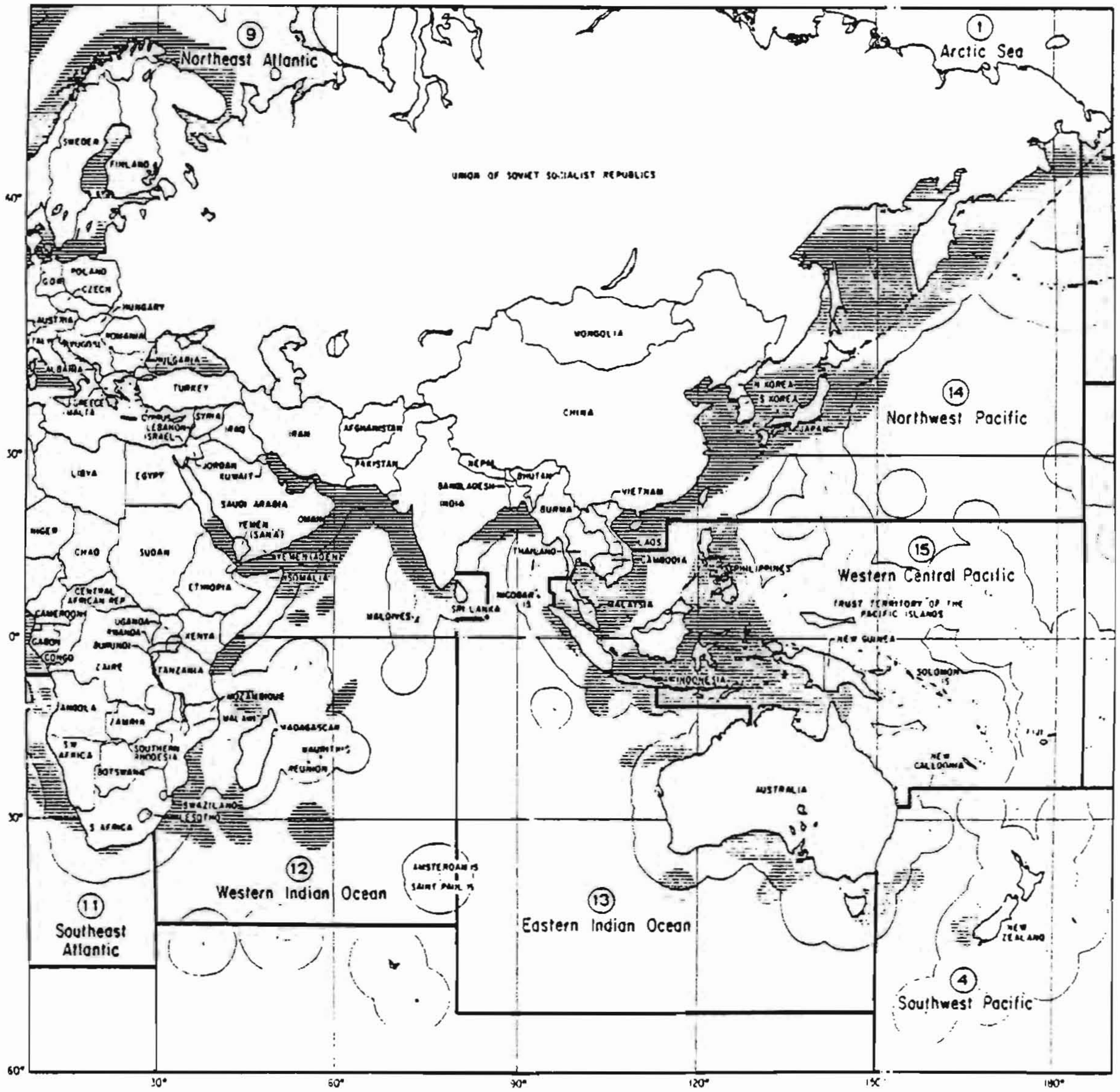
Table 4. Major species categories of world marine catch in 1976 (in millions of metric tons).

Diadromous Fishes	
(Sturgeon, salmon, shad, etc.)	1.45
Marine Fishes	55.10
Crustaceans	
(Lobster, shrimp, crab, etc.)	2.01
Molluscs	
(Oysters, clams, squid, etc.)	3.05
Aquatic Plants	
(Brown, red, green seaweeds)	1.29

Global Aspects of Marine Fisheries



AREA	MAJOR FISHERIES (in metric tons).	
1 *Arctic Sea*	(No figures available)	
2 *Northeast Pacific*	Alaskan Pollock	1,110,364
	North Pacific Hake	235,926
	Pacific Herring	120,947
	Pacific Cod	87,450
	Flatfish	75,596
	Pacific Ocean Perch	65,104
	Pink Salmon (Humpback)	62,070
	Yellowfin Sole	60,746
3 *Eastern Central Pacific*	Yellowfin Tuna	218,111
	North Pacific Anchovy	195,986
	Pacific Thread Herring	156,132
	California Pilchardi	142,306
	Skipjack Tuna	125,676
	Central Pacific Anchoveta	121,473
4 *Southwest Pacific*	Grenadiers	41,735
	Gadiformes	31,213
	Albacore	18,461
	Jack and Horse Mackerel	15,845
5 *Southeast Pacific*	Anchoveta (Peruvian Anchovy)	4,276,052
	Chilean Pilchard	489,284
	Chilean Jack Mackerel	377,293
	Pacific Silver (Chilean) Hake	133,509
6 *Northwest Atlantic*	Atlantic Cod	530,121
	Capelin	365,393
	Atlantic Herring	322,322
	Atlantic Menhaden	298,125
	Atlantic Mackerel	241,602
	Atlantic Redfish	181,060
	Silver Hake	177,528
7 *Western Central Atlantic*	Gulf Menhaden	561,453
	Spanish Sardine	42,227
	Grunts (Grunters)	21,435
	Mullet	17,105
	Clupeoids	15,932
	Weakfish	14,773
	Spotted Spanish Mackerel	14,623
	Red Grouper	14,573
8 *Southwest Atlantic*	Patagonian (Argentine) Hake	219,715
	Sardinellas	197,320
	White Croaker	86,910
	Weakfish	28,790
	Mullet	27,921
	Bluefish	27,257



Area	Species	Catch
9 *Northeast Atlantic*	Atlantic Cod	1,854,830
	Atlantic Herring	856,045
	Sprat	849,956
	Atlantic Mackerel	834,763
	Pollock	700,026
	Norway Pout	646,924
	Sand Eels/Sand Lances	519,766
	Atlantic Redfish	502,219
	Haddock	494,349
	Atlantic Horse Mackerel	353,696
10 *Eastern Central Atlantic*	Sardinellas	866,288
	Jack and Horse Mackerel	433,185
	European Pilchard	420,358
	Chub (Spanish) Mackerel	152,991
	Yellowfin Tuna	120,905
11 *Southeast Atlantic*	Cape Hake	817,273
	South African Pilchard	643,213
	Cape Horse Mackerel	530,820
	Cape Anchovy	306,743
	Cunene Horse Mackerel	118,105
12 *Western Indian Ocean*	Indian Oil-Sardine	290,586
	Clupeoids	165,142
	Anchovies	126,236
	Bombay-Duck	80,541
	Croakers, Drums	79,844
	Sardinellas	65,707
	Indian Mackerel	53,910
	Marine Catfish	52,612
	Yellowfin Tuna	36,770
13 *Eastern Indian Ocean'*	Clupeoids	92,942
	Ponyfish (Slipmouths)	45,775
	Hairtails Cutlass fishes	43,060
	Anchovies	35,329
	Croakers, Drums	30,996
	Indian Mackerel	20,542
14 *Northwest Pacific*	Alaskan Pollock	3,958,380
	Chub (Spanish) Mackerel	1,302,382
	Japanese Pilchard	1,056,958
	Japanese Anchovy	343,023
	Atka Mackerel	295,741
	Pacific Herring	252,141
	Flatfish	235,203
	Pacific Sand Lance	224,312
15 *Western Central Pacific*	Scads	495,972
	Skipjack Tuna	244,073
	Indian Mackerel	238,286
	Ponyfish (Slipmouths)	124,055
	Milkfish	113,102
	Sardinellas	107,197

Source: FAO. 1976 yearbook of fishery statistics.
Shaded areas on map indicate intense fishing zones.

Table 5. Per capita fish consumption averaged from 1972 to 1974 (in kilos).

Rank	Country	
1	Japan	69
2	Iceland	66
3	Portugal	58
4	Hong Kong	51
5	Singapore	48
6	Norway	47
7	Malaysia	41
8	Spain	38
9	Denmark	35
10	South Korea	34
—	United States	16
—	Canada	16

verification. The primary concept is that the environment has a limited capacity to support a given population of fish. The limiting factors tend to either increase mortality or suppress the physiological growth potential. The central thesis of sustainable fisheries is that exogenous mortality through fishing replaces the natural mortality and increases the intrinsic net natural rate of growth by reducing the standing stock — that is the smaller population reproduces at a greater rate and the fish grow faster. Both of these processes are limited and thus limit the potential yield. Harvests that exceed this limit, that is fisheries that generate a mortality that reduces the population below the point of maximum increase in growth, lead to what is termed "overfishing": the long-term yield is less than what potentially could be obtained.

The basic concepts are not unreasonable. They have been demonstrated in some laboratory experiments, and some fisheries have continued for a long time. However, the stability of fisheries has decreased markedly as fishing activity has increased. There also have been many demonstrations that the total mortality rate increases in proportion to fishing effort, and that natural mortality, in the absence of heavy fishing, is relatively low. There is, therefore, some doubt that man can be a prudent predator, taking only what would die or not be produced in his absence.

Table 6. United States fish supply for 1976 (in millions of metric tons).

	Domestic	Foreign
Edible	1.3 (37%)	2.2 (63%)*
Industrial	1.0 (73%)	.4 (27%)
Total	2.4(46%)	2.8 (54%)

*40% from Canada and Japan.

South Korean packing worker with fish products packaged for export trade. (FAO/UN photo)

The existing populations of marine plants and animals have evolved an intricate balance between themselves and their environment. This balance is based on population adjustments that provide the optimal reactions of populations to the natural ecological variations. The populations have co-evolved with a wide range of natural changes and are adapted to them. We do not understand the system well enough to predict these changes. Nevertheless, we know the populations can endure them, maintaining themselves in varying composition, but with generally the same productivity.

Marine animals have not co-evolved with man, and our interventions cause changes that are potentially very different from those the natural system has experienced. Man is not sensitive to the effects of these changes because he is not immediately dependent on them for survival. Our technology has developed to the point where we can drive the ecosystem into a state of disequilibrium from which recovery is unpredictable. The control we now exert in managing the populations is based entirely on a pervasive and intense fishing mortality that significantly alters population magnitude. The feedback takes place through our observation of effects and our reactions, both of which are constrained by an economics totally independent of that in the marine biosphere. The time span of changes in the ecosystem is likely quite out of phase with human desires. Our concepts of optimality are very different from nature's. Thus man's continuing activities in the marine ecosystem means that maintaining its productivity and realizing the estimated potential requires considerable restraint to prevent adverse changes.

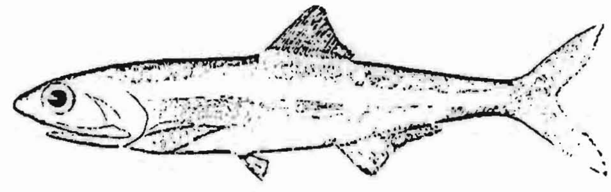
The Problems of Projection

The productivity of living marine resources generally is determined by two methods. One is based on estimating primary productivity, the production of protoplasm or carbon by photosynthesis, and then tracing the consumption of this primary food by animals upward through a food chain. Usually scientists begin by estimating the amount of phytoplankton (single-celled plants) in the water, but the figure for the world ocean is not yet very accurate. The conversion process is based mainly on theoretical assumptions of the amount of energy transferred between trophic layers. These trophic layers represent groups of biota that feed successively upon one another. Only a part of the prey's production is consumed by predators, and predator growth increment is only part of the total quantity consumed. The transfer efficiency may commonly vary from 5 to 40 percent; 10 to 15 percent are generally used in calculations.

There are several problems with this method. The estimates of potential depend to a great extent on definition of the trophic layers; how many are used and which groups of species are included. These decisions or judgments can change estimates by factors of 10 or 100. It is not always clear what is assumed; what animals are included in the different levels. Not all of the production in the ocean is available to man. Perhaps something like 30 to 40 percent of the annual production of fish and shellfish can be harvested on a continuing basis. The remainder is needed within the biomass as energy to maintain itself. The most reliable studies based on this approach indicate that the potential harvest is about 150 million metric tons. This includes animals that we are not used to eating and which cannot now be economically harvested.

The tropho-dynamic estimates of productivity tend to be higher than those produced by the second method of fishery-based estimates. The former is estimating a resource potential that includes the total organic biomass in arbitrary categories and is not directly restrained by the limitations of practical and feasible fisheries. The latter utilizes observations of actual fishery yields and field surveys of the resources, and incorporates the utilization factors in terms of past performance.

Most of the productive ocean areas have been exploited to some degree. Potential, therefore, can be estimated by examining the available statistics and extrapolating from them. Lack of accurate reports limits the accuracy of such estimates, of course, as does the inference that past



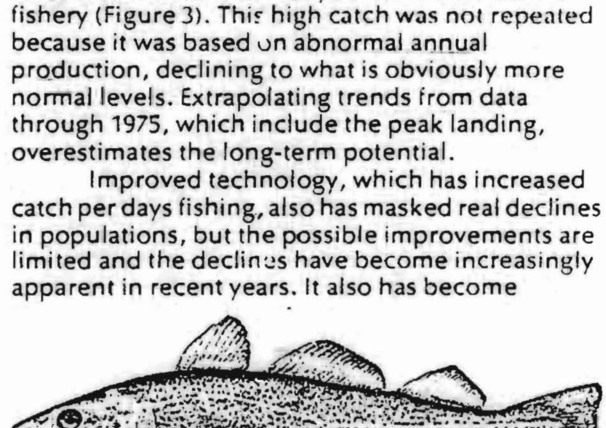
Striped anchovy *(Anchoa hepsetus)*

performance reflects future potential. Where only experimental surveys of standing stock are available, assumptions must be made about the annual production rate and the proportion available for long-term harvest, similar to the tropho-dynamic approach.

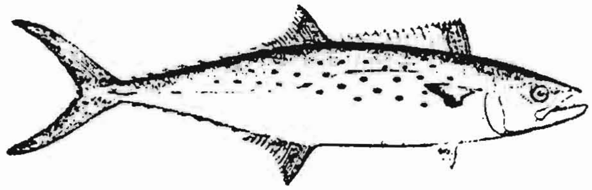
The fishery-based estimate figures have increased with time, a characteristic of trend extrapolation methods. Some estimates assume that past trends could be linearly extrapolated in time, and that laws of diminishing returns (limits of biological productivity) would not apply for some time yet. The more specific estimates often have been based on the concept and method of single-species models and on data from rapidly developing fisheries that were not stabilized to the extent needed for accurate estimates, and which, because of the opportunistic nature of fisheries, were based on short-term, above-average population magnitudes.

Animal populations do cycle, and fisheries seldom are started at population lows. An exceptionally well-documented and perhaps typical example is the mackerel fishery off the east coast of the United States. Americans have fished the population since the early 1800s, with peak annual catches every 10 to 25 years of 50,000 to 80,000 metric tons. The average long-term catch was considerably less than this (Figure 2). In 1967, a very good year class (survivors of one year's spawning) was produced, and the catch, at that time mostly by foreign countries, peaked in 1974 at more than 400,000 metric tons as that year class entered the fishery (Figure 3). This high catch was not repeated because it was based on abnormal annual production, declining to what is obviously more normal levels. Extrapolating trends from data through 1975, which include the peak landing, overestimates the long-term potential.

Improved technology, which has increased catch per days fishing, also has masked real declines in populations, but the possible improvements are limited and the declines have become increasingly apparent in recent years. It also has become



Cod *(Gadus callarias)*



Spanish mackerel *(Scomberomorus maculatus)*

apparent that previously observed highs in cycles cannot necessarily be achieved again after intense exploitation. The potential for a population to react to a favorable environment is lessened after a high mortality has been exerted on it. This appears true, at least, of 10- to 20-year time spans within which the majority of intense fisheries have been developed. This may be caused in part by changes in species abundance triggered by selective exploitation.

Interspecific relations have not been included explicitly in most estimates of potential. It is documented that shifts in species composition have taken place in some intensely exploited areas. Off the coast of California, the sardine population decreased after heavy fishing to be replaced by the anchovy. In the North Sea multiple-species fishery, such changes also have been observed; some of the replacement populations tend to be of the smaller-sized, shorter-lifespan species. In some cases, total yield has been maintained, but often through heavier fishing. In other cases, total yield has decreased, perhaps because species are less desirable and fishing slacks off.

In any event, although fishing has been directed at certain desired species, gear has not been as selective as the taste of markets. The fishing mortality, in many cases, has been directed at large biomass populations, partly because of the development of long-distance, large-vessel fleets, but also because of the search for profit in coastal fisheries. In any mixed-species population, which not by accident occurs in most productive areas, fishing mortality also has been exerted on species caught incidentally, and often has been greater than that which will maintain initial yields. Thus, in general, total area yield, in many cases, has proven to be less than estimates based on individual species assessment. In addition, many estimates include organisms not yet subjected to exploitation, but which are the major food of predators under exploitation and hence in much reduced abundance.

The potential of prey populations is often estimated by calculating the amounts consumed by predators at times in the past when the number of predators were significantly larger — for example, in the case of krill, estimates of potential are derived from calculating whale krill consumption in the past, and matching that figure against the present consumption by heavily reduced stocks, the difference being the surplus that is theoretically available. This system of figuring, however, is questionable, because it is not certain that what was

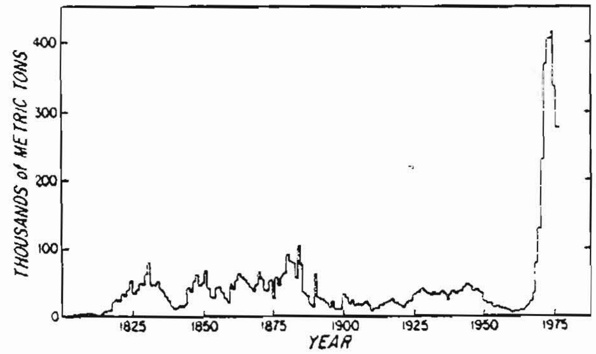


Figure 2. Landings of mackerel from the Northwest Atlantic.

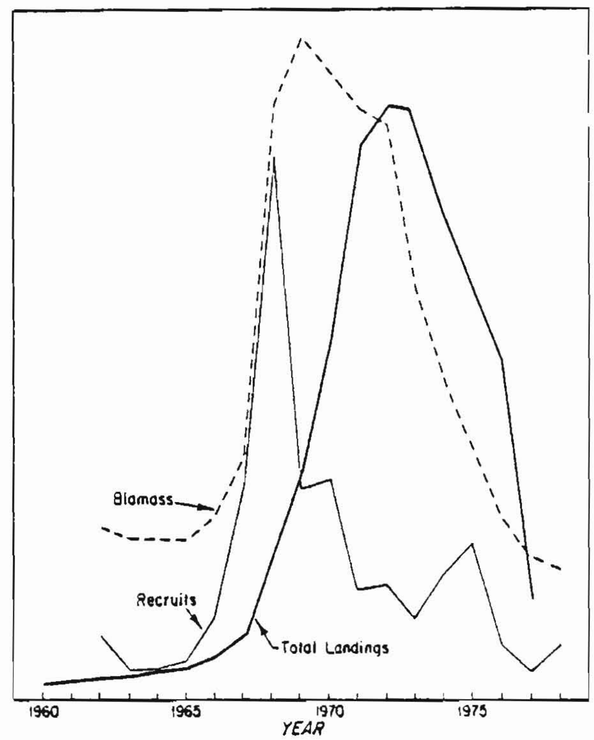
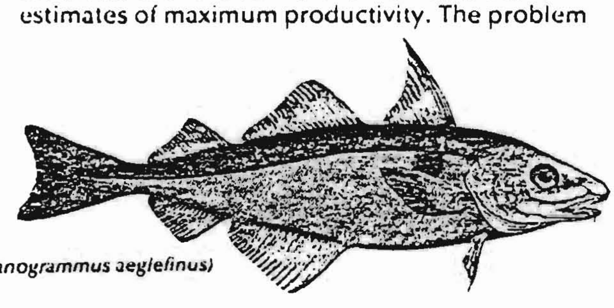


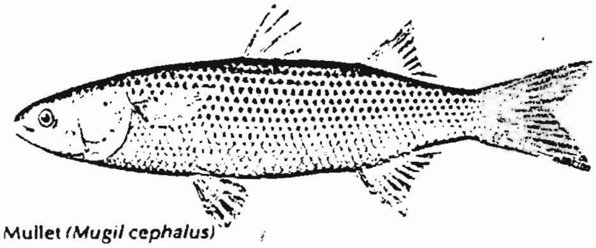
Figure 3. Recent trends in the Northwest Atlantic mackerel population and fishery.

once consumed by predators becomes available to man in the absence of the predator.

The effect of interaction between species is a rather important aspect most often neglected. The pertinent question is whether the overall productivity of fish biomass is greater than, equal to, or less than the sum of the individual stock estimates of maximum productivity. The problem



Haddock *(Melanogrammus aeglefinus)*



Mullet *(Mugil cephalus)*

arises when traditional single-species methods of assessment are applied to directed-species fisheries. Evidence from fisheries observation, tank experiments, and modeling indicates that present estimates of potential are probably too high because of these inter-specific factors. The most recent estimates based on fisheries data range from 120 to 450 million metric tons. It may well be that maximum potential only will be achieved by utilizing species in general proportion to their natural composition — that is, because of the uncertainty of the effects of intense fishing, the best strategy may be to take fish as they come and not attempt population manipulations.

Several other factors probably will contribute to reduced fishing yields — the first being political. Living marine resources are considered globally as common property to be held and managed in perpetual trust. The scope of commonality recently has been reduced by the extended coastal jurisdictions. Division by national boundaries is totally artificial with respect to the resource and, to a lesser extent, the same is true of the offshore limits. Because of differing concepts of optimality and management, national objectives may be quite differently perceived, even for the same population. The result tends to be further exacerbation of the disharmony between man and nature, which must be reversed if there is to be reasonable utilization of the resource. In fact, national objectives of economic optimization in domestic fisheries already have reduced some foreign fishing within extended coastal zones, and further restrictions probably will be effected. This is particularly significant in temperate water zones where the heaviest exploitation and highest catch now occur, but the effect has been and will be felt elsewhere.

Secondly, up to this time a natural environment has been assumed when estimating the productivity of marine resources. This assumption can no longer be maintained. The effects of man's impact on the environment are much more subtle and probably longer lasting than those of the fisheries.

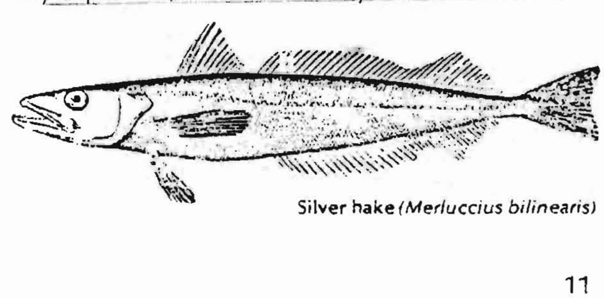
Pollution is largely a result of industrialization and thus most discernible in the Northern Hemisphere. Pollutants are being introduced into the ocean in quantities that are beginning to significantly affect living resources. Productivity is being reduced through change of habitat and bio-accumulation of chemicals, particularly in the estuarine areas of developed countries. Airborne pollution, however, is now detectable even in the open sea. Some pollution occurs in dramatic form — oiled beaches or poisoning by heavy metals. The more important effects, however, stem from largely unnoticed chronic, low-level pollution, a result of society's willingness to regard the oceans — again because of their vastness — as a natural receptacle for man's wastes.

In order to understand how pollutants affect living marine resources, we first must understand the mechanisms behind natural ocean processes, and then be able to predict the effects of a disturbance. It is unlikely that we will reach that point of sophistication rapidly enough to detect and correct our mistakes in the near future. Thus it is prudent to assume, until we know more, that rates of oceanic pollution will increase and that the result will be reduced yields of marine resources.

Resources of the Future

The world catch of aquatic animals and plants is reported annually by the Food and Agriculture Organization of the United Nations with varying degrees of accuracy. Statistics from China (see page 21) and the Antarctic are rough estimates, for example, while those of leading fishing countries for northern temperate waters are much more precise. Examination of these data indicates that most of the traditional fisheries catch remained constant or decreased over the last six years, despite increased fishing activity. In the recent decade, the fisheries have been maintained essentially by shifting to different populations of the same species, or to different species with similar market characteristics. Thus the relatively unfished populations of the broad and productive northwest Atlantic Coast were exploited by long-distance fleets from 1961 through 1972, seeking at first cod, haddock, and herring. Yields from these have decreased significantly in recent years, and probably will not rise again in the near future.

Significant capelin fisheries have developed over the last five years both to accommodate the increased fishing fleet capacity and to replace declining yields of herring. The same has occurred in the prolific North Sea area, where sprat and blue whiting, for example, are being harvested to replace declining herring and mackerel stocks. Crustacean and mollusc catches have not increased much in total amounts. It must be concluded that the productive coastal shelves of the world are being fully exploited, and it is unlikely that a sustained



Silver hake *(Merluccius bilinearis)*

increase of the present traditional fisheries catch of about 60 million metric tons will be achieved in the future. It should be noted that preliminary figures for the 1977 world catch show a decrease of nearly two million metric tons from 1976.

Technological and social developments in the next 25 years, therefore, will not cause an increase in sustained yield of the traditional marine fisheries. Technological advances likely will be needed just to keep the cost of fishing in line with market values. To maintain present yields also will require development of more markets for a wide variety of species in order to take advantage of inevitable cyclic changes in species productivity, and implementation of conservation management practices. Where, then, is the potential for increased yields?

The actual theoretical potential of marine protein is quite large — from 10 to 100 times that provided by traditional fishery forms — if one assumes that plankton and very small vertebrates can and will be utilized. There are a number of serious difficulties involved, supply and demand being the most immediate. A direct comparison of today's fishery efficiencies with the difference in plankton and fish densities illustrates the magnitude of the problem. The most efficient fisheries catch about 50 metric tons of fish per day. The same efficiency applied to zooplankton would produce much less than half a ton per day. Even if the means of harvest can be developed, there are innumerable problems in processing for which no solutions now exist.

Antarctic krill may be an exception (see page 13). Large annual yields could be harvested within the next 10 or 15 years, but there are problems. Recent exploratory expeditions have encountered patchy and variable distributions. The Antarctic weather restricts feasible operations to the summer months. Establishment of a fishery requires a large stern trawler with specialized processing equipment, a vessel at least as large as the biggest trawlers existing today. Krill trawlers easily could cost $10 million each, and it probably would require hundreds of them to meet the minimal estimated potential of 10 million metric tons. Then there is the acceptability of the product; among other things, krill are extremely perishable relative to most fish. They frequently retain green phytoplankton and other food that cause problems in processing. Thus, even assuming an adequate resource, it will require time, technological development, intensive marketing and considerable amounts of money — and luck — to build up a multi-million ton fishery.

There also has been some potential mentioned for developing fisheries on meso-pelagic fishes — for example, lantern fishes (distributed mostly in areas outside national jurisdictions). Again, processing and economic considerations probably will hamper development. They are widely but sparsely distributed. Populations of squid in the open ocean (seaward of the continental shelves) are another possibility. Observations indicate that individual squid are quite large. This could mean that they are old, that productivity is low; we do not have enough information to determine the potential.

In summary, it appears that although fisheries are developing for species not hitherto heavily exploited, these largely replace yields from failing fisheries. The evidence also suggests that further development is quite limited. Given political and economic restraints, it is doubtful that the current marine catch of about 60 million metric tons will be increased much by the year 2000. It may, in the short run, be difficult even to maintain the current yield.

In any event, the potential of world fisheries will be met only through wise management based on a thorough understanding of the ecosystem. The principal ecological research required should deal with the fundamental processes whereby energy is transformed and distributed in the ecosystem, and with the effects of abiotic factors on productivity and species success.

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References and Further Reading

Food and Agriculture Organization. 1977. 1976 yearbook of fishery statistics. Catches and landings. Vol. 42. Rome: FAO.

Goldberg, E. D. 1976. *The health of the oceans.* Paris: UNESCO Press.

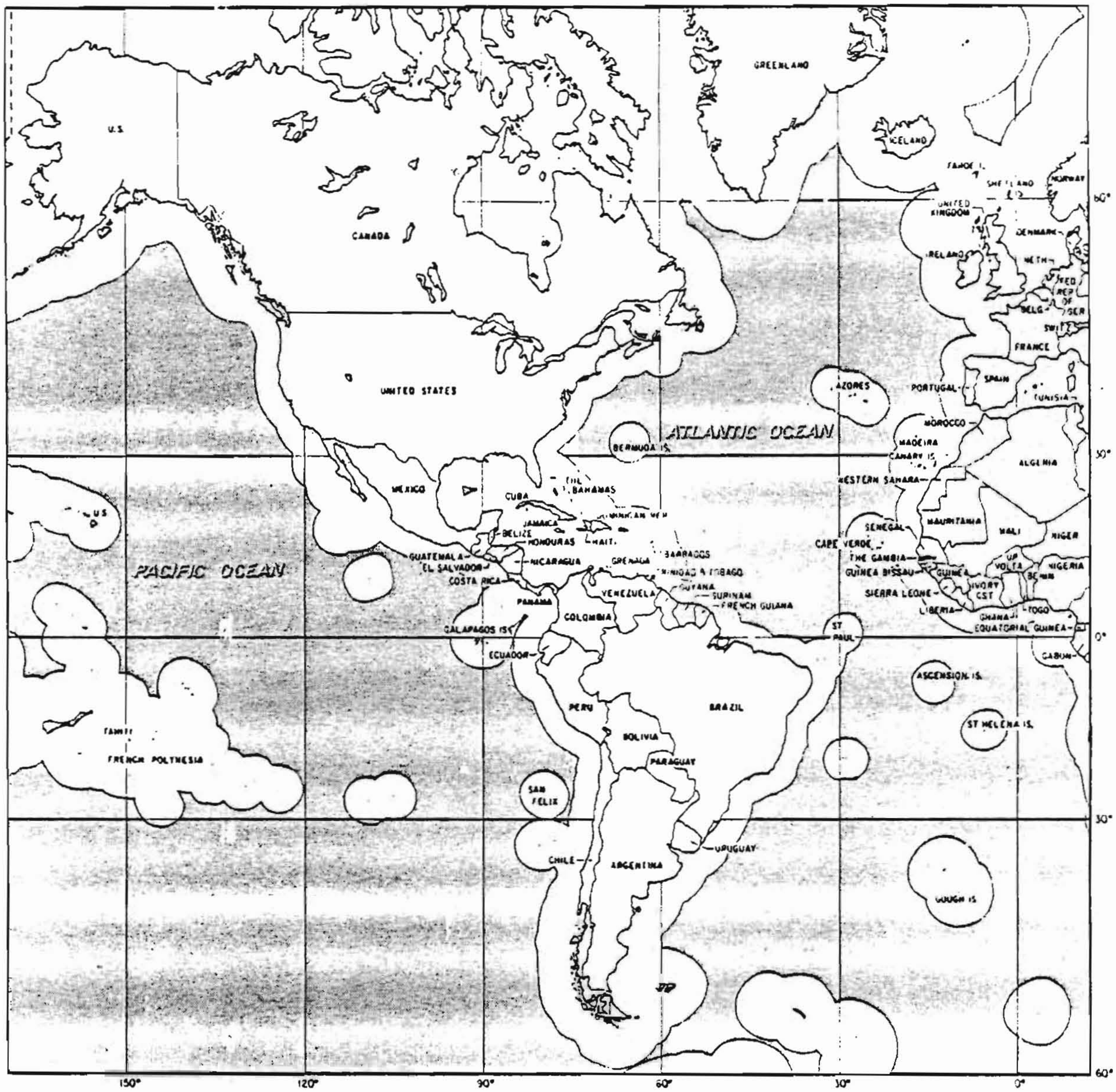
Gulland, J. A. 1971. Fish resources of the ocean. *Fishing News.* West Byfleet, England: FAO.

Hood, D., ed. 1971. *Impingement of man on the ocean.* New York: Wiley Interscience.

National Academy of Sciences. 1969. Resources and man. Committee on Resources and Man, National Academy of Sciences, National Research Council. San Francisco: W. H. Freeman and Co.

Source: Oceanus. "Food From The Sea". vol. 18:2 Winter 1975.

Global Effect of 200-Mile Claims



NATIONAL FISHING MARITIME CLAIMS

in Nautical Miles, as of January 3, 1979
[TERRITORIAL SEA CLAIMS IN BRACKETS]
(200-MILE ECONOMIC ZONES IN PARENTHESES)

3 Miles — 5 Countries

Bahrain [3]
Jordan [illegible]
Qatar [3]
Singapore [3]
United Arab Emirates [3]*

6 Miles — 3 Countries

Greece [6]
Israel [6]
Lebanon [No Legislation]

12 Miles — 37 Countries

Algeria [12]
Australia [3]
Belgium [3]
Bulgaria [12]
China [12]
Cyprus [12]
Djibouti [12]
Dominica [3]
Egypt [12]
Equatorial Guinea [12]
Ethiopia [12]
Fiji [12]
Finland [4]
Honduras [12]
Indonesia [12]
Iraq [12]
Italy [12]
Jamaica [12]
Kenya [12]
Kuwait [12]
Libya [12]
Malaysia [12]
Monaco [12]
Nauru [12]
Rumania [12]
Saudi Arabia [12]
Sudan [12]
Syria [12]
Taiwan [3]
Thailand [12]
Trinidad and Tobago [12]
Tunisia [12]
Turkey [6]
Western Samoa [12]
Yemen (Sana) [12]
Yugoslavia [12]
Zaire [12]

15 Miles — 1 Country

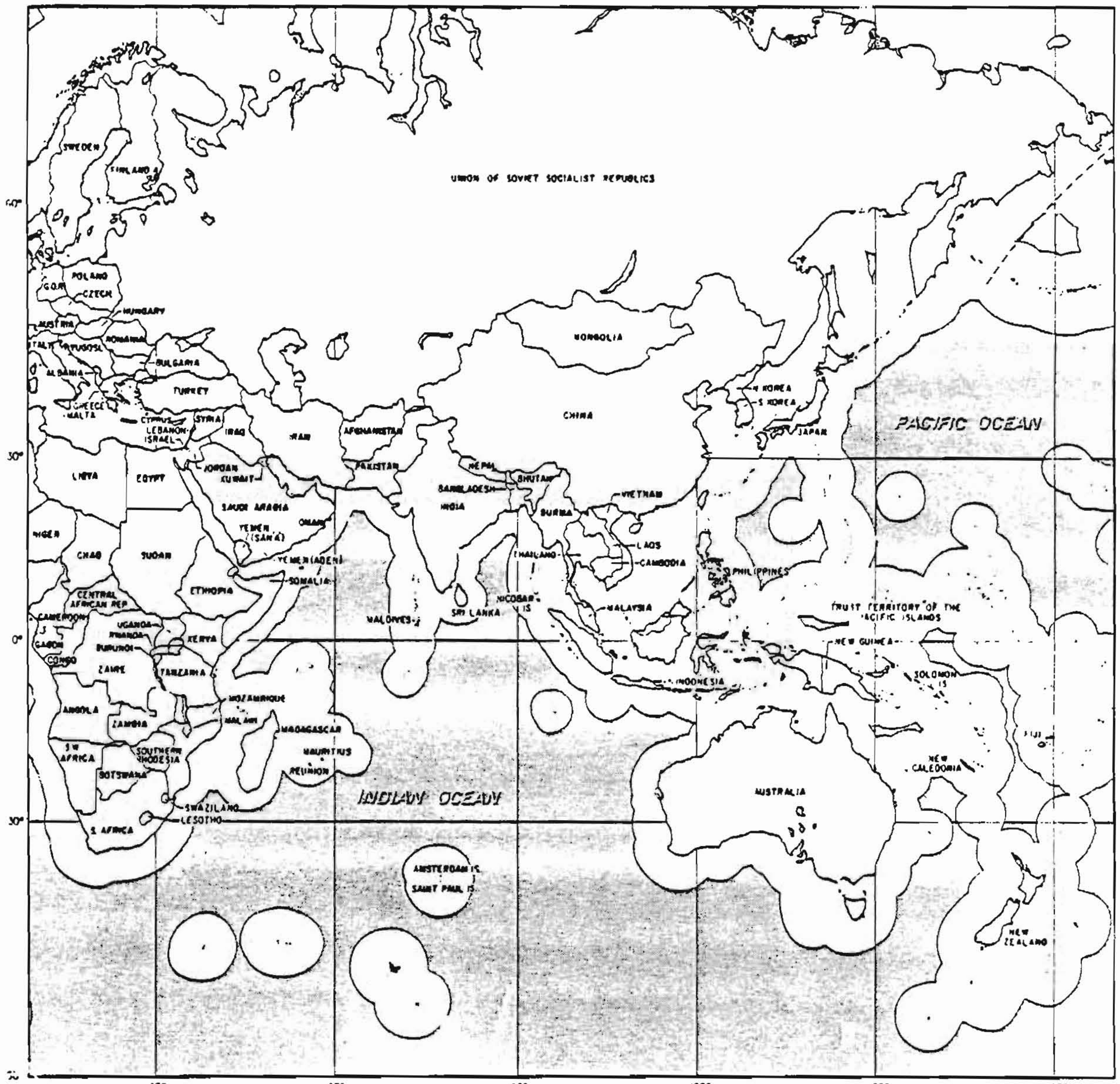
Albania [15]

25 Miles — 1 Country

Malta [12]

***Except for Sharjah, which has a 12-mile limit.**

Source: U.S. State Department, Office of the Geographer.



50 Miles — 4 Countries

Cameroon [50]
Iran [12]
Gambia, The [50]
Tanzania [50]

70 Miles — 1 Country

Morocco [12]

150 Miles — 2 Countries

Gabon [100]
Madagascar [50] (200)

200 Miles — 76 Countries

Angola [20]
Argentina [200]
Bahamas, The [3]
Bangladesh [12] (200)
Barbados [12] (200)
Benin [200]
Brazil [200]
Britain [3]
Burma [12] (200)
Canada [12]
Cape Verde [12] (200)
Chile [3]
Colombia [12] (200)
Comoros [12] (200)
Congo [200]
Costa Rica [12] (200)
Cuba [12] (200)
Denmark (plus Greenland and the Faroes) [3]
Dominican Republic [6] (200)
East Germany [3]
Ecuador [200]
El Salvador [200]
France [12] (200)
Ghana [200]
Grenada [12] (200)
Guatemala [12] (200)
Guinea [200]
Guinea-Bissau [12] (200)
Guyana [12] (200)
Haiti [12] (200)
Iceland [4]
India [12] (200)
Ireland [3]
Ivory Coast [12] (200)
Japan [12]
Kampuchea [12] (200)
Liberia [200]
Mauritania [70] (200)
Mauritius [12] (200)
Mexico [12] (200)
Mozambique [12] (200)
Netherlands [3]
New Zealand [12] (200)
Nicaragua [3]
Nigeria [30] (200)
North Korea [12] (200)
Norway [4] (200)
Oman [12]
Pakistan [12] (200)
Panama [200]
Papua New Guinea [12] (200)
Peru [200]
Poland [12]
Portugal [12] (200)
Sao Tome & Principe [12] (200)
Senegal [150] (200)
Seychelles [12] (200)
Sierra Leone [200]
Solomon Islands [3]
Somalia [200]
South Africa [12]
South Korea [12]
Soviet Union [12]
Spain [12] (200)
Sri Lanka [12] (200)
Surinam [12] (200)
Sweden [4]
Togo [30] (200)
United States [3]
Uruguay [200]
Venezuela [12] (200)
Vietnam [12] (200)
West Germany [3]
Yemen (Aden) [12] (200)

Rectangular/Polygonal Claim — 3 Countries

Maldives (200)
Philippines
Tonga

<u>New England Fisheries/Aquaculture</u>

<u>Fisheries: Study Questions</u>:

<u>Antartic Krill: Protein of the Last Frontier</u>

by Sayed Z. Ed-Sayed and Mary Alice McWhinnie

1. Describe the Antartic Krill, its location, and its protein potential. Comment on the significance of its swarming habits.

2. Explain the technological level of the krill industry at present. Which nations are conducting experimentations and research in the Antartic krill industry? Why?

3. Comment on the krill consumption in the upper trophic levels of the oceans.

4. What would be some of the effects of man's krill harvest?

5. What is the current status of a large krill fishery in the Antartic waters?

ANTARCTIC KRILL:

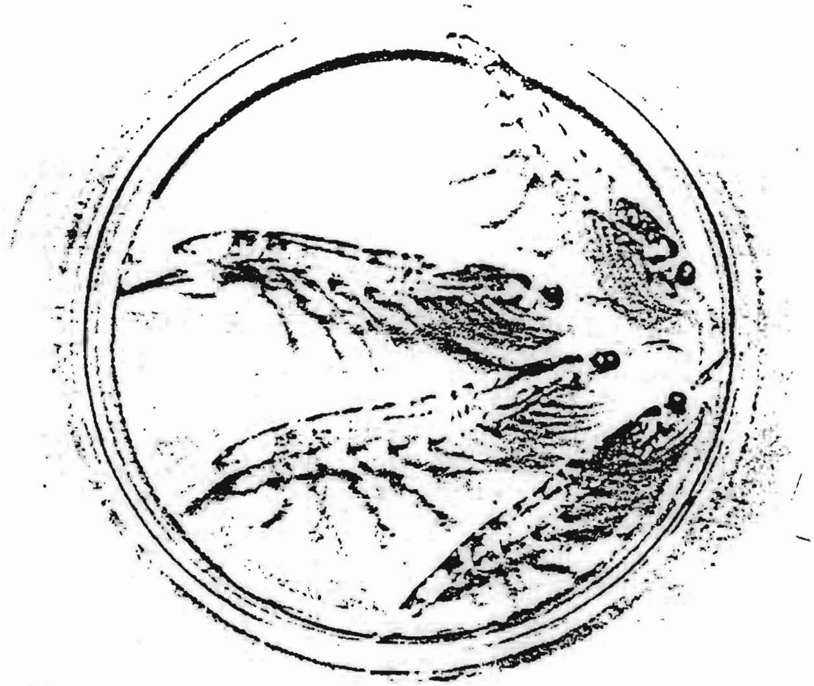


Figure 1. Live krill Euphausia superba, *collected in Antarctic waters.*

Protein of the Last Frontier

by Sayed Z. El-Sayed and Mary Alice McWhinnie

Recently one of us (SZE) received a letter from a free-lance writer, requesting information about a subject that in recent years has attracted wide attention among fisheries biologists, conservationists, politicians, foreign affairs officers, and international lawyers, to name just a few. The subject was Antarctic krill. The writer requested answers to the following:

- *Has the reduction in the whale population resulted in a corresponding increase in the krill population?*
- *What seem to be the most serious obstacles to large-scale krill harvesting?*
- *Prior to the early 1970s only the Soviet Union took much interest in krill; why do you think the Russians were the first?*
- *Some say krill is the largest untapped source of protein in the world; in your opinion, is it worth the time and effort to try to tap it?*

Undoubtedly these questions are on the minds of the professionals and non-professionals alike who are seeking answers to many of the vexing problems that our free-lancer posed in his letter. Seldom in the history of civilization has the development of a new fishery been heralded with the same intensity of concern that now attends the development of the Antarctic krill fishery. This concern stems from the fact that statements have appeared both in the popular press and scientific publications arousing public attention to the harvesting of 100 to 150 million tons of Antarctic krill. To a burgeoning and protein-hungry world population, the prospects of a krill harvest of nearly double the annual world catch of marine fish and shellfish (about 60 million metric tons in 1976) takes on a dramatic aspect.

At the center of all this activity is the shrimp-like crustacean *Euphausia superba* (krill), a 4- to 7-centimeter-long creature that is only one of the some 86 euphausiids species found in the world's oceans (Figure 1). Krill is the key organism in the Antarctic food web upon which all higher species — whales, seals, penguins, winged birds, fish, and squid — depend, directly or indirectly, for their food (see *Oceanus*, Summer 1975, p. 40).

The existence of large stocks of krill in the Antarctic has been known for many years, but interest in their commercial exploitation arose in the early 1960s with the decline of whaling in the Southern Hemisphere. There are several other forces that brought attention to the potential exploitation of krill stocks. Among these are the dwindling stocks of conventional fishes due to excessive harvesting pressure; the recent move by coastal states to establish 200-mile exclusive economic zones, thus forcing long-distance fishing fleets to hunt for harvests outside national jurisdiction (see page 60); and the recent improvements in the equipment required to detect, catch, and process large concentrations of small organisms. These factors, together with human population growth and the increased demand for more animal protein, have led to the search for other potential food sources, and in particular the virtually untouched krill stocks. When these factors are coupled with potential climate changes (see *Oceanus*, Fall 1978), that will most certainly affect quantities and patterns of conventional agricultural production, the urgency to develop a new protein resource becomes even more evident.

The Organism

As a result of the extensive investigations carried out during the British *Discovery* expedition in the 1920s and 1930s, almost all that is known about krill comes from the classic studies of the late J.W.S. Marr of that expedition. Of the 11 species of Antarctic krill, the most important are *Euphausia superba, E. crystallorophias, Thysanöessa macrura,* and *E. valentini*. These euphausiids are located as follows: north of the Antarctic convergence is *E. valentini;* in the pack ice, *E. crystallorophias;* and in open waters south of the convergence, dense patches of the larger species *E. frigida* and *E. superba*.

The largest concentrations of *Euphausia superba* are in the Atlantic sector, particularly in the northern Weddell Sea, the Scotia Sea north of the Orkney Islands, around the South Shetland Islands and west of the South Sandwich Islands (Figure 2). Breeding takes place in at least four areas: the Bellingshausen Sea, the Bransfield Strait, the Davis Sea, and in the vicinity of South Georgia. The number of breeding stocks is largely unknown; however, there is a possibility of at least two separate ones. It is believed that krill spawn once or twice a year (for one or two years); fecundity is between 2,000 to 3,000 eggs per spawning. Longevity is still a matter of controversy; however, there are indications that krill may live for more than four years.

Krill tend to congregate in large swarms of a single age class. These swarms average 40 by 60 meters in size, with a maximum recorded dimension of 600 meters. According to Soviet scientists, krill swarms can extend to depths of 40 or 50 meters, although concentrations most suitable for commercial catch are found between 1 and 10 meters.

The swarming habit makes it easy for baleen whales to feed on these animals, with blue whales preferring adolescent krill, and fin whales favoring adults (see *Oceanus*, Spring 1978). It has been shown that adult and juvenile krill are often found in separate layers, with the juveniles being closer to the surface. The fact that different age groups of *Euphausia superba* swarm separately may be useful for commercial harvesting and fishing management.

The Fishery

The Soviets and the Japanese started experimental krill fishing in 1961-62. In recent years, several other countries have been pursuing this type of fishing, notably Poland, West Germany, South Korea, and Taiwan. In 1974, Japanese vessels reported average yields of 16 tons per day. In 1975-76, the West German trawler *Weser* averaged 8 to 12 tons of krill per hour of towing time, with a maximum catch of 35 tons in 8 minutes (Figure 3)! It is difficult to assess the relevance of these figures or to compare them with those of commercial vessels since much of the time spent in experimental fishing has been devoted to reconnaissance. The technology required to evaluate the extent of the krill resource is still in the formative stage. Nonetheless, available information suggests that, technological impediments notwithstanding, a commercial fishery for krill could develop quickly.

Krill processing, like krill harvesting, was pioneered by the Soviets and the Japanese, who in the early 1960s produced krill meal and krill protein concentrate. Now a large range of krill products is available from more advanced processing techniques (Figure 4). In the early 1970s, the Soviets began marketing krill-butter and krill-cheese spread products. The new brand Okean, currently sold in supermarkets in Moscow at about $1.35 a pound, is recommended, according to *The New York Times*, to enrich such dishes as Siberian dumplings, meat pies, fish balls, salads, paté and deviled eggs. The Soviets also claim medicinal values for krill paste, ranging from treating hyperacidity of the stomach to atherosclerosis.

The Japanese are making a type of fish sausage with 20 percent of the fish replaced by krill, while the Soviets have developed a sausage with coagulated krill paste, structured by an alginate gel. Last year, the West Germans produced a krill mixture with the consistency of a Bruhwurst, containing cooked krill forcemeat, fish, and milk protein.

Despite the recent substantial gains in our

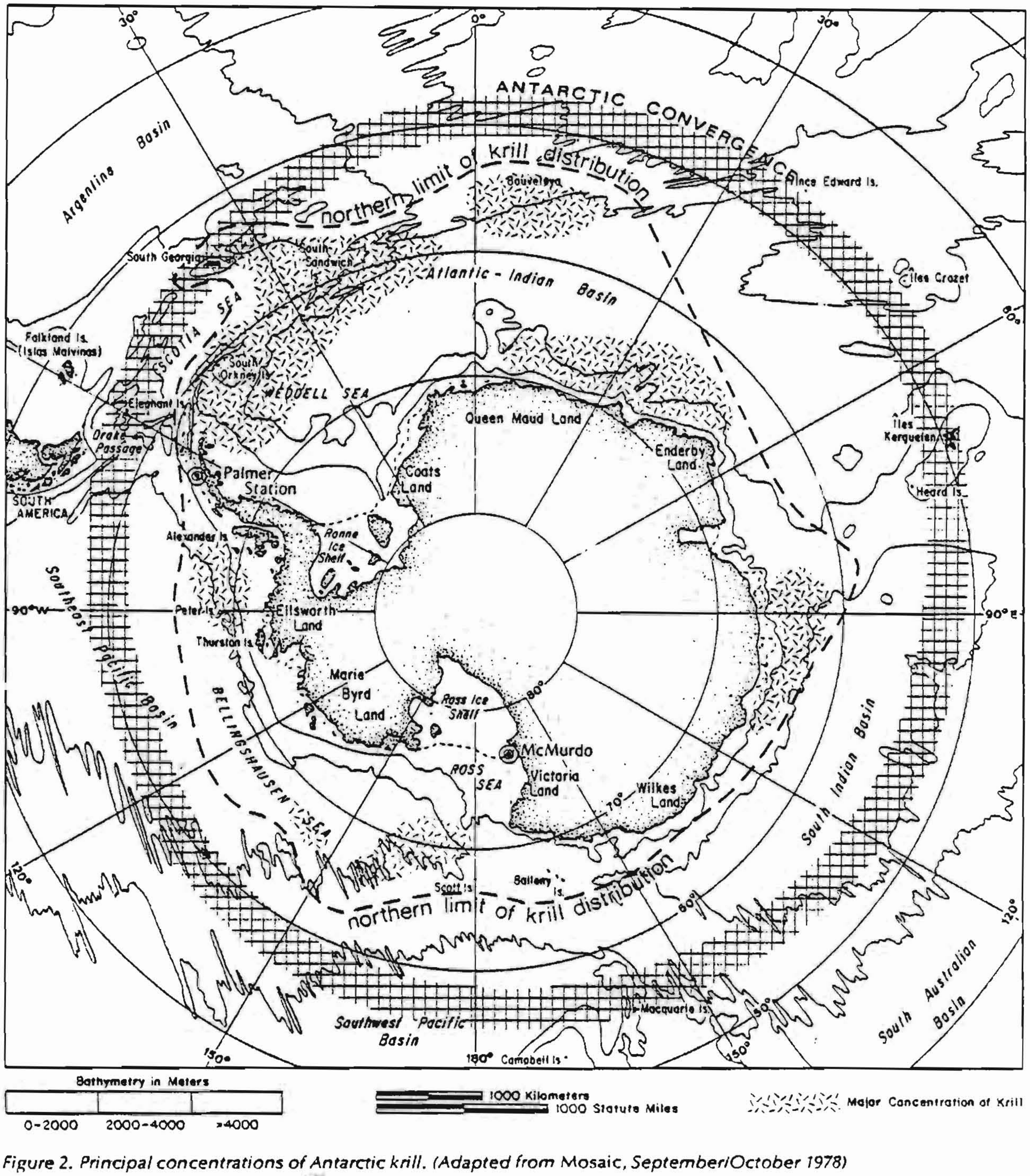


Figure 2. Principal concentrations of Antarctic krill. (Adapted from Mosaic, *September/October 1978)*

knowledge of krill harvesting and processing technologies, these procedures have not been fully developed. The economics of harvesting a remote fishery, the potential salability of krill products, and the development of markets have not been determined. However, it appears unlikely that the landed cost of krill will be less than that of conventional fish and seafood resources.

In the interest of the most efficient management of a living resource, there is a need to know many details of the life history of the species targeted for exploitation. While broad outlines of the life history of *Euphausia superba* were drawn sometime ago (Ruud, 1932; Bargmann, 1945; Marr, 1962; Mackintosh, 1968, 1970, 1972, 1973; Nemoto and Nasu, 1975; among many others), many

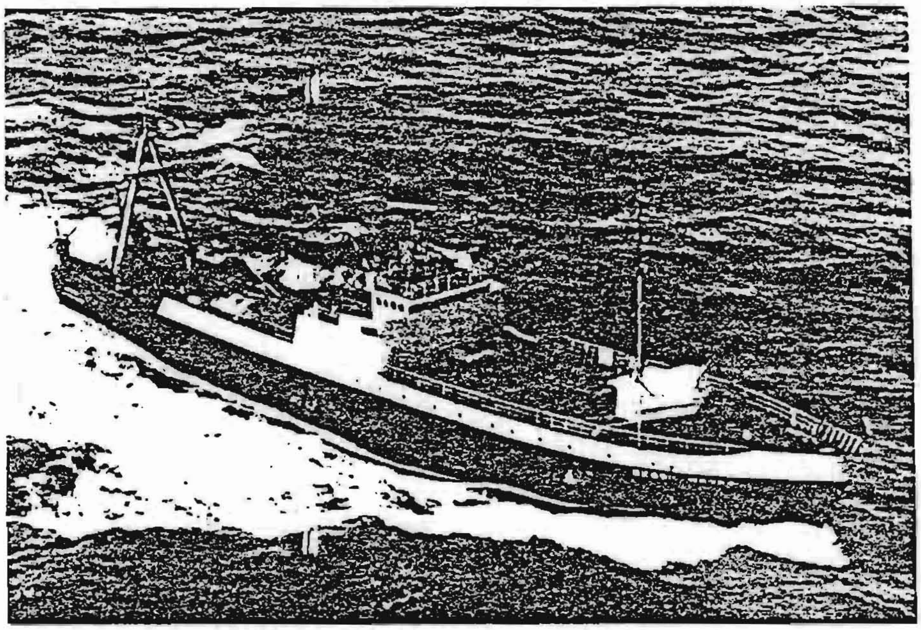


Figure 3. The West German trawler Weser *in Antarctic waters.*

fundamental questions remain unanswered, specifically concerning krill biology, distribution, population dynamics, standing stocks, and production. At the present time, Antarctic krill are being harvested at the rate of 80,000 to 90,000 metric tons annually.

Krill Biology

While most aspects of krill biology are under intensive study, definitive answers are needed to questions on growth rates, rate of advance to maturity, longevity, fecundity, and spawning potential. Moreover, as harvesting is underway at several widely spaced sites, it is necessary to know the number of spawning events, temporal and spatial differences within the populations throughout their circumpolar range, and the factors inducing their spawning behavior.

Let us consider the question of krill feeding. Until recently, krill have been considered to be exclusive herbivores and thus primary consumers in the ecosystem. It probably is still true that during the austral summer they extensively graze on the abundant phytoplankton stocks. But McWhinnie and Denys (1978) have reported that krill also have carnivorous, detritivorous, and cannibalistic habits, which will require revision of their annual growth rates and ultimately their longevity, as well as energy transfer throughout the ecosystem. Winter feeding and growth had been considered to be negligible when phytoplankton productivity decreased due to extensive ice cover in the seas adjacent to Antarctica. However, during 12 months of laboratory experiments at Palmer Station, Antarctica, the author (MAM) and co-workers showed that carnivorous and cannibalistic feeding probably continue throughout the year.

Another question involves the relationship between the distribution of krill and their physical/chemical milieu. The Southern circumpolar seas often are considered to be

Figure 4. Advertisements for krill dishes in Japan.

relatively uniform in thermal regime and radiant energy (however, variable seasonally). Their physical oceanographic characteristics have well-known vertical and horizontal variabilities, but these and other environmental parameters have not been fully correlated with krill distribution (Deacon, 1977). Inter-seasonal and inter-annual variations in krill populations also add to the list of unknown factors. British scientists (Bonner, Everson, and Prince, 1978) reported an apparent shortage of krill in the 1977-78 season around South Georgia, a region known to be one of the major feeding grounds of baleen whales. Young Antarctic fur seals showed a corresponding loss of weight, and there was a low survival rate among black-browed albatross chicks and Gentoo penguin chicks compared with earlier years.

Krill Stocks

Estimates of the standing stocks of krill, as well as of the extent of dependence of many species on this food source vary widely. Great discontinuities in the distribution and swarming behavior of krill populations, as well as the diverse methods of estimating standing stocks, are responsible for this high variance. Estimates of krill stocks range from 125 to 200 million metric tons (Everson, 1977; Sahrhage and Steinberg, 1975) to 3.5 to 5 billion metric tons (Bogdanov, 1977), to 6 billion metric tons (Lubimova, *et al*, 1973). The bases from which these estimates were made, coupled with the relatively small areas in which sampling was conducted, render the exercise in determining krill stocks both tenuous and less than useful. However, it is clear that krill stocks are of considerable magnitude. Although seasonal and annual variations are known, they generally have not entered into computations. Nonetheless, inter-annual differences are known to occur (cold versus warm years), with harvesting success being inconsistent on an annual basis (poor, for instance, in 1977-78).

Krill Consumption

Estimates of krill utilization by species in the upper trophic levels — such as whales, seals, and penguins — are as variable as those for the standing stocks of krill. This, too, can be expected when the areal extent of the Antarctic seas (38 million square kilometers) and the dimensions of the coastal areas and their surrounding ice are considered. Moreover, logistic constraints, the character of weather and sea conditions, and the relative brevity of the austral summer (during which most studies are conducted), together account for our limited understanding of this ecosystem.

The most recent estimate of krill consumption by baleen whales, which have an estimated population of about 338,000, is about 33 million tons annually. Crabeater seals, which feed almost exclusively on krill, are the most abundant in numbers — estimated at 25 million; they consume nearly 100 million tons of krill annually. Leopard, Ross, and fur seals also feed on krill, with an estimated consumption of about 4 million metric tons, although their main food sources are fish and squid. At present, crabeater seals appear to consume more krill than any other animals in the system (Figure 5).

The seven species of penguins and the 19 species of winged birds (petrels, albatrosses, and others) have a total population estimated at 188 million, consuming about 39 million tons of krill annually — about equal to that consumed by baleen whales.

We have no reliable estimates on the standing stocks of the other two major consumers of krill — namely fish and squid. There is evidence in the literature that these two groups consume between 100 to 200 million metric tons of krill annually.

Thus, if we combine the estimates of krill consumption by all directly dependent consumer species, it comes to roughly 400 million metric tons annually. It is clear that this total consumption equals or exceeds the minimum estimate for the standing stocks of krill. On the other hand, the total consumer utilization is only 13 percent of the next highest estimate for standing krill stocks — 3.5 billion metric tons.

Annual production is even less well known than the other parameters of the Antarctic ecosystem. Few have attempted computations because data are so incomplete. However, these values range from 13 to 20 million metric tons per year (Rakusa-Suszczewski, 1976), to 75 to 100 million metric tons (Hempel, 1968), to 400 million metric tons annually. Thus it would pose a considerable threat to the Antarctic ecosystem if one were to proceed rapidly toward a large commercial fishery when basic production estimates vary from 20- to 30-fold.

Effects of Man's Krill Harvest

Sooner or later, the problems posed by man's potential harvest of krill must be faced. The Antarctic food pyramid is characterized by large numbers of individual species that make up relatively simple food chains. Krill provide the link between the primary producers — for example, phytoplankton — and the higher trophic levels — fish, birds, and mammals (the latter being consumed by only a few carnivores). It is a peculiarity of the Antarctic ecosystem that one herbivore species, krill, supports five diverse groups, and many species of predators. The ecosystem manages so well because each species exploits a different segment of the krill population, thus reducing competition. Nonetheless, one inherent weakness of the system is its great dependency on a single organism. Therein lies the danger in man's harvest of the creature.

Man is the principal predator of whales. With krill harvesting, he will become the exploiter of both prey and predator! Commercial krill harvesting will likely take place in the areas of greatest krill concentration. These are precisely the areas where whales feed. Because of the annual seasonal migration of whales, the time of year for whale feeding will coincide with the commercial harvesting of krill. The would-be effects on the ecological system as a result of this competition are not clear, but the impact of man's harvest, most assuredly, would cause reverberations in the ecosystem. Because whales are long-lived species, there would be a time lag in the response of the ecosystem to any harvest of krill. It is therefore difficult to estimate what the long-term effects of a large krill harvest would be.

Could the overharvesting of whale stocks have caused a krill surplus? This argument, advanced in recent years, is based on the difference between the amount of krill consumed by the much larger stocks in the 1930s and that of present-day stocks. The surplus is estimated at about 150 million tons. Although there is little firm evidence that such a surplus exists, the increased numbers of seals, penguins, and winged birds counted in recent years could account for additional amounts of krill, which may have been channeled to other consumers as well.

Some fishery experts are advocating a catch limitation on krill that is low enough to provide a minimum risk to the ecosystem. At the same time, they have been urging that an accurate data base be obtained before catch limits are established. They are of the opinion that the harvest of krill should be structured so as to maximize the information gained by catch data.

Biomass: Concepts and Programs

In 1972, the Scientific Committee on Antarctic Research (SCAR) established a small group of specialists to expand the scientific understanding of the Antarctic marine ecosystem. From the beginning of discussions on research needs, SCAR sought collaboration with the Scientific Committee on Oceanic Research (SCOR), the International Association of Biological Oceanography (IABO), and the Advisory Council of Marine Resources Research (ACMRR) of the Food and Agriculture Organization of the United Nations. This group has recently been reconstituted as the SCAR/SCOR/IABO/ACMRR Group of Specialists on Living Resources of the Southern Oceans. The group has worked in liason with the Intergovernmental Oceanographic Commission (IOC), and particularly with its International Coordination Group for the Southern Ocean. The IOC has encouraged SCAR in its development of research programs, which hopefully will provide the scientific information necessary for sound decisions by governments.

In the summer of 1976, the United States hosted the First Conference on Living Resources of the Southern Ocean at the National Academy of Sciences' summer studies center in Woods Hole, Massachusetts. The conference's chief objective was to review the present knowledge of the living resources of the Southern Ocean and to develop proposals for future cooperative studies in the area. The proposals became known as Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS).

The principal objective of BIOMASS is to gain a deeper understanding of the structure and dynamics of the Antarctic marine ecosystem as a basis for future management of potential living resources. The ultimate objective of BIOMASS would be achieved by producing a predictive model for the entire system. It is clear that krill would play a central role in this model, both as the major herbivore and the dominant food for most of the organisms higher in the trophic levels.

At its meeting in Kiel, West Germany, last year, the Group of Specialists proposed an organizational structure consisting of three permanent technical groups — program implementation and coordination; methods; and data, statistics, and resource evaluation — and four shorter-term working parties — on krill abundance, krill biology, fish biology, and physical/chemical oceanographic observations. The austral summer of 1980-81 was chosen for the First International BIOMASS Experiment (FIBEX): as many as 20 ships from 13 countries are scheduled to participate in the multidisciplinary study of the variabilities of ecological parameters in space and time. FIBEX will concentrate on the Atlantic sector, including the Drake Passage and its western approaches. The Second International BIOMASS Experiment (SIBEX) is scheduled for 1984-85, with the overall program lasting between eight and ten years.

International Aspects

While the scientific specialists were occupied in drafting BIOMASS and preparing for the FIBEX experiment, the signatory nations to the Antarctic Treaty were grappling with the diplomatic and resource management problems. And to complicate matters, landlocked and developing countries at United Nations Law of the Sea negotiations began demanding a share in the profits from exploitation of "common heritage" resources, even though they do not have the technology to exploit such resources.

In early 1978, the 13 signatory nations to the Antarctic Treaty met in Canberra, Australia, to begin negotiating a convention on the conservation of Antarctic marine living resources. (Commercial whaling and sealing operations are currently governed by the International Whaling Convention and the Convention on Antarctic Seals.) It had been hoped that the living resources convention would be signed by the end of 1978, but it has been delayed.

It is understood that the convention will provide for comprehensive research into krill ecology, and a monitored quota system, based on

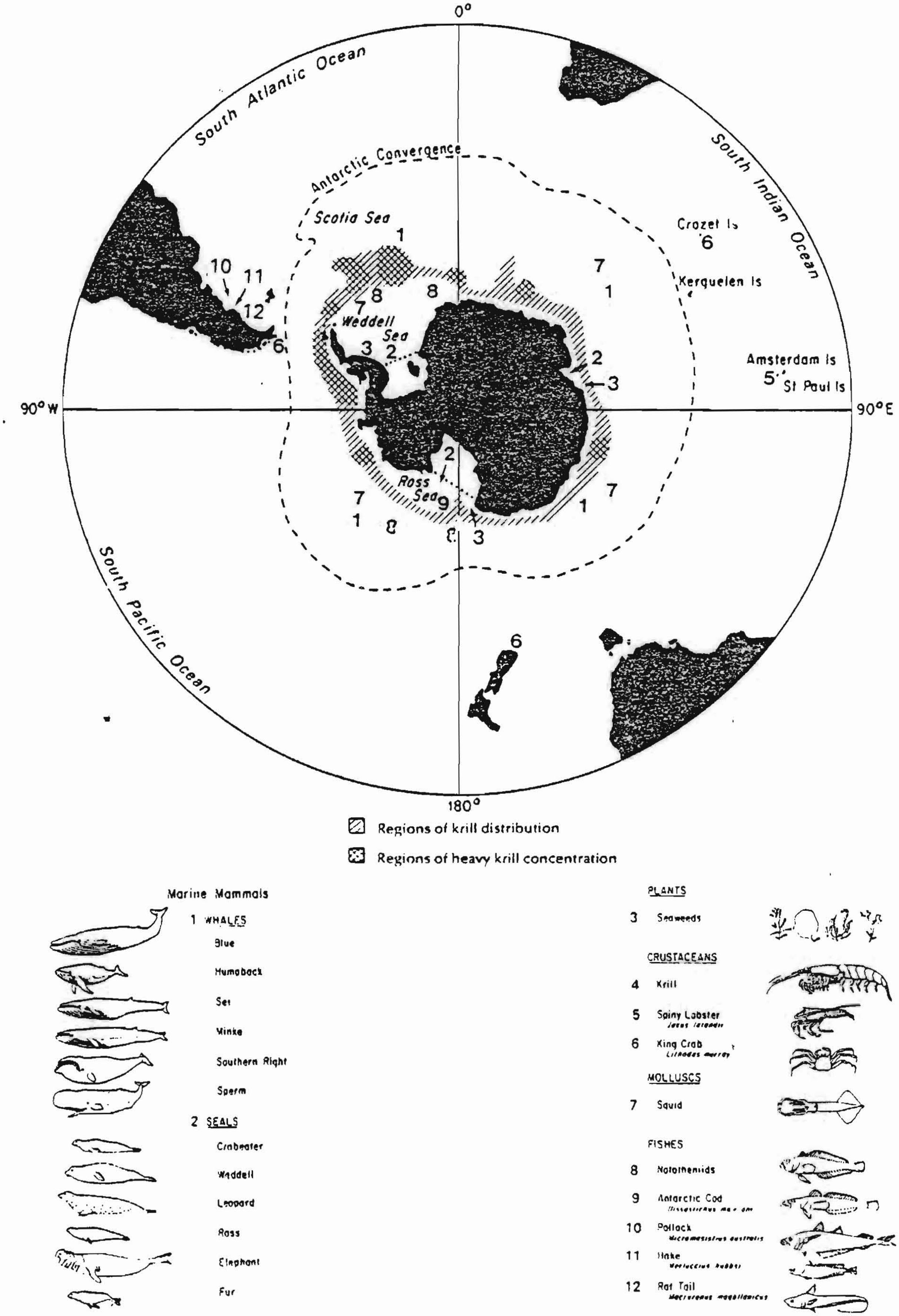


Figure 5. Living resources of the Southern Ocean.

gradually expanding knowledge about krill. The convention will set up a commission to facilitate research, compile and publish data, identify conservation needs, adopt conservation measures, and generally work toward implementing the conservation principles so strongly advocated by the scientific community.

Future Research Needs

The foregoing overview of the possibility of a large krill fishery in Antarctic waters is intended to put the idea into a realistic perspective as opposed to the optimistic view of many, who see it as a panacea for the problem of world protein needs. As present studies show, this ecosystem is not "simplistic"; a great deal of information is lacking in areas of critical concern, such as biology, distribution, and stock assessment, among others.

In any development of a successful fishery, research programs should be designed so as to consider the entire ecosystem. The "species-by-species approach" has, time and again, proven inadequate and faulty. Thus any attempt at harvesting a single species without regard to possible effects on other components in the system may set up irreversible reactions that will result in major changes in the ecosystem. This is especially evident in the Antarctic, where the ecosystem is considered simple, where some of the dominant krill consumers already are under protective conventions, where harvesting comes close to an area that is protected by international treaty, and where long-term nutritional benefits are tightly coupled with conservation goals.

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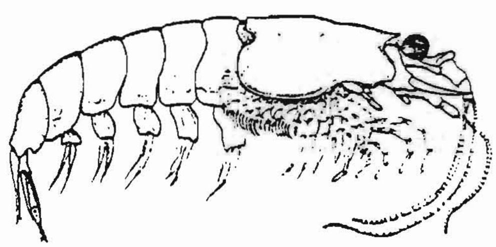

Literature Cited

Bargmann, H. E. 1945. The development and life history of adolescent and adult krill, *Euphausia superba*. *Discovery Reports* 23: 103-176.

Bogdanov, A. S. 1977. Oral presentation. IOC, IGOS/SOC. London. (September, 1977).

Bonner, W. N., I. Everson, and P. A. Prince. 1978. A shortage of krill, *Euphausia superba*, around South Georgia. International Council for the Exploration of the Sea, by the Biological Oceanography Committee "C. M. 1978/L:22 (Mimeo)."

Deacon, Sir George. 1977. Ocean Science in the Antarctic. SCOR Workshop on Identifying Problems of the Southern Ocean, Wormley, England, 15-16 March, 1977 (Appendix V).

El-Sayed, S. Z. 1975. Biology of the Southern Ocean. *Oceanus* 18(4): 40-49.

Everson, I. 1977-78. *In press*. Krill and squid, resource review. BIOMASS, Volume 2: Selected Contributions to the Woods Hole Conference on Living Resources of the Southern Ocean, 1976. Ed. by S. Z. El-Sayed, (SCAR/SCOR, Biological Investigations of the Marine Antarctic Systems and Stocks).

Hempel, G. 1968. Area reviews on living resources of the world's ocean. Antarctic preliminary draft. FAO Fisheries Circular No. 109.3.

Lubimova, T. G., A. G. Naumov, and L. L. Lagunov. 1973. Prospects for the utilization of krill and other non-conventional resources of the world ocean. *Jour. Fish. Bd. Canada* 30: 2196-2201.

Mackintosh, N. A. 1966. The swarming of krill and problems of estimating standing stock. *The Norwegian Whaling Gazetteer* No. 11: 213-16.

Mackintosh, N. A. 1970. Whales and krill in the twentieth century. In *Antarctic ecology*, vol. 1: 195-212. Ed. M. W. Holdgate. Proceedings of the 2nd SCAR Symposium on Antarctic Biology. London: Academic Press.

———. 1972. Life cycle of Antarctic krill in relation to ice and water conditions. *Discovery Reports* 36: 1-94.

———. 1973. Distribution of post-larval krill in the Antarctic. *Discovery Reports* 36: 95-156.

Marr, J. W. S. 1962. The natural history and geography of the Antarctic krill (*Euphausia superba* Dana). *Discovery Report* 32: 33-464.

McWhinnie, M. A., and C. J. Denys. 1979. *In press*. Biological studies of Antarctic krill, austral summer, 1977-1978. *Antarctic Jour. of the United States*.

Nemoto, T., and K. Nasu. 1975. Present status of exploitation and biology of krill in the Antarctic. Oceanology Internatl. 1975 Conference, Brighton, England, pp. 353-60.

Rakusa-Suszczewski, S. 1976. Report to SCAR group of specialists on the Antarctic living marine resources, Woods Hole Conference, August.

Ruud, J. T. 1932. On the biology of the souther Euphausiidae. *Hvalrad. Skr. Oslo* 2: 1-105.

Sahrhage, D., and R. Steinberg. 1975. Dem Krill auf der Spur/Expedition in Antarktishe Gewasser. *Umschau*. 75(20): 627-31.

Source: Oceanus. "Food From the Sea". vol. 18:2 Winter 1975.

New England Fisheries/Aquaculture

Fisheries: Study Guestions

World Fisheries to 2000: Supply, Demand, and Management
by M.A. Robinson

After reading this article and studying the graphs explain what you consider to be most significant issues relative to the supply, demand, and management of world fisheries by the year 2000. Give specific reasons for your conclusions.

World fisheries to 2000

Supply, demand and management

M.A. Robinson

In the past decade the rate of growth of world fish catch has declined sharply. Looking towards the end of this century, the author examines trends in fishery production throughout the world and employs projections of future catch by species group and geographical area. Possibilities of catch increases, future trends in supply and demand, and the main areas of action for future development and rational management of fisheries are discussed and evaluated.

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This article is a slightly modified version of Chapter 6 on fisheries in FAO's recent study of long-term trends in world food and agriculture, *Agriculture: Toward 2000*, which was reviewed by the FAO Conference in November 1979.

The author wishes to acknowledge valuable help with the statistical material given by his colleague Ms Adele Crispoldi.

In the past decade there has been a profound change in world fisheries. In fact, 1969 was the first year since good statistics became available that the world catch fell and, although it increased sharply in 1970, growth since then has been both erratic and slow. Although most projections made in the late 1960s were influenced significantly by the Indicative World Plan and the growing number of fully exploited stocks, it was not foreseen that the rate of growth of the world catch would decline so soon and so sharply (see Table 1).

The process of growth and stagnation of the world fish catch during the past two decades has been much influenced by the growth and decline of fisheries exploited largely for reduction of their landings to meal and oil. These fisheries accounted for 60% of the rise in production in the period 1960-70. Likewise, since 1970 the fall of over 5 million tons in landings used for reduction has largely accounted for the slow growth in the world catch. Predominant among these fisheries was that for the anchoveta of the Peru current from which Chile and Peru combined increased their landings by 9 million tons between 1960 and 1970; but catches from this fishery have since declined from a peak of 13 million tons in the latter year to about 1.5 million tons. The north-east Atlantic herring fisheries have suffered a very similar fate – the Atlanto-Scandian herring in particular reaching a peak of 1.7 million tons in 1968, but now not yielding catches of commercial significance. In addition to the much reduced anchoveta catches, world fishmeal production is mainly sustained by capelin, a small marine salmonoid fish, and by a variety of other species, particularly mackerels and sardine.

In contrast to landings for reduction to meal and oil, production of fish for direct human consumption has grown steadily throughout the 1960s and 1970s, although the rate of growth has declined since 1970. The increase in the landings of food fish in the developed world has come largely from a few countries, namely Japan, the USSR and the centrally planned countries of eastern Europe and Spain.

In the developing countries the increase has been more widespread, although in some countries, eg Thailand, the Republic of Korea and Ghana, it has been exceptionally rapid; in others, eg some Middle Eastern countries, it has been rather slow. Further, in some countries a significant proportion of the catch increase has been of high-value

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Table 1. World production of living aquatic organisms.

	Production (million tons)			Increase (million tons)		Rate of increase (%/year)	
	1960	1970	1977	1970/60	1977/70	1970/60	1977/70
Total	40.2	70.7	73.5	30.5	2.8	5.8	0.5
Developing countries	17.0	36.1	34.2	19.1	– 1.9	7.8	– 0.6
Developed countries	23.2	34.6	39.3	11.4	4.7	4.1	1.8
Food	31.6	44.7	52.9	13.1	8.2	3.5	2.4
Developing countries	13.1	21.6	28.2	8.5	6.6	5.1	3.9
Developed countries	18.5	23.1	24.7	4.6	1.6	2.2	0.9
Non-food	8.6	26.0	20.6	17.4	– 5.4	11.7	– 3.2
Developing countries	3.9	14.5	6.0	10.6	– 8.5	14.0	– 13.0
Developed countries	4.7	11.5	14.6	6.8	3.1	9.3	3.5

species such as crustaceans and tuna destined largely for export markets; thus consumption has grown more slowly than production. In general, however, it remains true that in almost all countries where fish is an important element in the diet, there has been an increase in per capita consumption during the past 15 years.

Trends in trade in fishery products closely reflect changes in production. Thus the volume of fishmeal exports declined sharply in the early 1970s from a peak of 3.5 million tons in 1968, and continues to fluctuate at a level about 1.5 million tons below this. Fish oil has shared in this decline, but trade in products for human consumption has, in most cases, increased.[1]

Possibilities of catch increases

The growth of food fish production in developing countries is one of the few trends in world fisheries that has continued throughout the 1960s and 1970s, but it has not been sufficient to prevent the rate of growth of total world catch from declining drastically – from about 6% in the 1960s to less than 1% in the 1970s. The basic cause of this decline is the diminishing number of stocks of those conventional fish[2] which offer the possibility of sustained increase in catch.

The present level of exploitation compared with the commercially realizable potential of broad groups of conventional types of marine fish, crustaceans and cephalopods is shown in Table 2. This indicates that marine catches can probably be increased by a further 20 million to 30 million tons over present levels.[3] The data, however, need to be interpreted with caution because only a part of this theoretical increase in catch is realizable through increased fishing and a substantial part, possibly as much as 50%, will be achieved only by better management.

This is especially true with regard to pelagic species which offer considerable possibilities of catch increases and which well illustrate the divergent forms of action required to produce them. For those stocks, such as the anchovy of the Peru current and the herring of the north-east Atlantic, which have collapsed and are now yielding much lower catches, careful management in the form of strict control of fishing effort is required if catches from these stocks are to increase to anything like their former levels. For other stocks of shoaling pelagic fish, such as the herring of the Patagonian shelf or the sardine of the north-west Arabian Sea, increased yields will require an increase in fishing effort.

[1] Shellfish exports in particular have increased to the advantage of the balance of payments of many developing countries in Asia and Latin America. Trade in frozen fish has also grown with exports from developing countries playing an increasingly important role.

[2] Conventional fish are those harvestable by existing types of gear and readily marketable in existing product forms.

[3] The sum of the potential of all stocks considered in islation would give a potential up to perhaps 20% greater than that shown in Table 2. It is, however, practically impossible to exploit all stocks on a sustained basis to 100% of their potential for reasons concerned with species interaction, unintended catches of one species while fishing for another etc, and the full potential of conventional stocks of the world's oceans given in the table has been discounted by 20% to allow for the effect of these factors.

Table 2. Catch of marine fish, crustaceans and cephalopods (1977) and estimated potential[a] by marine areas and species[b] (million tons).

	Oceanic pelagic		Demersal		Shoaling pelagic		Cephalopods		Crustaceans		Total	
	1977 Catch	Potential	1977 Catch	Potential	1977 Catch	Potential	1977 Catch	Potential	1977 Catch	Potential	1977 Catch	Potential
Atlantic Ocean												
North-west	0.01		1.21	2.24	0.89	1.60	0.13	?	0.13	0.16	2.37	
North-east	0.06		5.71	4.80	6.28	6.40	0.03	0.80	0.15	0.17	12.23	
Western central	0.06		0.25	2.00–2.80	0.63	1.60–2.80	0.01	0.50	0.25	0.32	1.20	
Eastern central	0.31	0.88	0.76	0.80	2.45	2.50	0.15	0.20	0.03	0.03	3.70	>31.49–>33.49
South-west	0.02		0.69	2.00	0.27	1.20	0.00	>0.80	0.11	0.11	1.09	
South-east	0.03		0.82	>0.80	1.85	2.00	0.00	0.04	0.03	0.04	2.73	
Antarctic	–		0.17	?	0.00	?	0.00	?	–	–	0.17	
Total Atlantic	0.49	0.88	9.61	12.64–>13.44	12.37	14.80–16.00	0.32	>2.34	0.70	0.83	23.49	>31.49–>33.49
Pacific Ocean												
North-west	0.75		7.55	9.00	6.43	6.00	0.81	0.81	0.36	0.40	15.90	
North-east	0.23		1.17	1.92	0.12	0.96	0.00	0.08	0.22	0.24	1.74	
Western central	0.69		1.13	3.20–4.00	2.90	3.20–4.00	0.13	0.16	0.45	0.48	5.30	
Eastern central	0.41	2.20	0.12	0.80	1.10	1.60–2.00	0.01	0.40–0.80	0.08	0.40	1.72	37.81–46.61
South-west	0.04		0.26	0.80	0.11	0.80	0.06	0.12	0.01	0.01	0.48	
South-east	0.03		0.29	0.56	3.38	3.20–9.60	0.00	0.40	0.06	0.07	3.76	
Antarctic	–		–	–	–	–	–	–	0.00	?	0.00	
Total Pacific	2.15	2.20	10.52	16.28–17.08	14.04	15.76–23.36	1.01	1.97–2.37	1.18	1.60	28.90	37.81–46.61
Indian Ocean												
Western	0.20		0.50	1.20	1.31	2.12	0.03	0.24	0.25	0.25	2.29	
Eastern	0.08	0.56	0.49	1.00	0.60	0.82	0.00	0.16	0.09	0.11	1.26	6.46
Antarctic	–		0.11	?	0.00	?	–	–	0.01	?	0.12	
Total Indian	0.28	0.56	1.10	2.20	1.91	2.94	0.03	0.40	0.35	0.36	3.67	6.46
Mediterranean	0.03	0.04	0.32	0.40	0.66	0.80	0.05	0.06	0.03	0.04	1.09	1.34
World total	2.95	3.68	21.55	31.52–>33.12	28.98	34.30–43.10	1.41	>4.77–>5.17	2.26	2.83	57.15	>77.1–>87.9

a see textual discussion of Table and Ref 2.

b Excludes molluscs other than cephalopods and unconventional species, eg krill

Source. FAO estimates.

Less spectacular but still significant increases in catch can be expected from the better management of demersal species, particularly flounders and cod. Among the species for which increases in fishing effort will yield higher catches, the best commercial prospects are for hake and similar species off the southern coasts of South America, in particular for the hake on the Patagonian shelf. These stocks, however, are already attracting considerable attention, and in the not too distant future may not have much potential remaining unexploited. Elsewhere, especially in the southern hemisphere and in tropical waters, there are unexploited resources, but because much of this potential consists of a wide variety of species with none in any great abundance, their commercial utilization will present, and in fact already presents, serious marketing problems.

The possibilities of increased production of shellfish are generally good; future levels of output of many other products are likely to depend as much on market considerations as on resource availability. For example, cephalopods (squids, cuttlefish, octopus etc) are, in many areas of the world, only lightly exploited but at the same time are regarded as conventional foods in only a few countries. Thus, without some considerable product development or consumer education, the full potential of such valuable resources seems unlikely to be realized even by the end of this century.[4] Given the control of pollution and the availability of seed, good prospects exist for the cultivation of other molluscs such as oysters, clams and scallops.

Crustaceans generally are heavily exploited, but some increases in catch can be foreseen, eg from smaller crabs and from some shrimps, including those in deeper waters and in some as yet rather undersurveyed areas such as the north-west coast of Australia. In the long term, however, the supply of shrimp is likely to become increasingly inelastic and thus the consequent rising prices will give impetus to the culture of these animals. For many species the technical problems of culture have been solved, and provided fry are available and the necessary environmental conditions (temperature, salinity etc) exist, the main determinant of increased output from culture will be the cost of inputs (mainly feed) in relation to the price of shrimp. Even though it is increasing and likely to double or treble, the amount of shrimp cultured by the end of this century is likely to remain small, ie less than 10% of total production.

Although some growth of freshwater fisheries can be expected, the most interesting developments in this sector over the next 20 years are likely to be changes in the sources of production. For both electricity generation and irrigation, interference with natural river basin systems seems likely to continue unabated with a consequent continuing decline in rivers and flood plains, while output from reservoirs and intensive aquaculture can be expected to increase.

The possibilities of cultivating molluscs and crustaceans are considered above. Similar considerations apply to fish: the main technical problems of expanding production are seed provision and the supply of water of the right quality, while the input–output relationship represents the main economic constraint. Fish are generally hardier animals than shrimp (and some molluscs, eg oysters), and food requirements for the culture of some species are less demanding, which partly explains the more rapid progress in the culture of fish compared with shrimp. Cultured fish currently

[4] Consumer acceptance is also a factor likely to govern the production of mussels; possibilities for their production by culture are very great indeed.

Table 3. Aquatic organisms – actual and estimated production.

	Production (million tons)					Rate of increase (%/year)				
	1963[a]	1975[b]	1980	1990	2000	1974-76 / 1961-65	1980 / 1974-76	1990 / 1980	2000 / 1990	2000 / 1974-76
World	47.7	72.5	75.3	84.7	92.5	3.6	0.7	1.2	0.9	1.0
Developing countries	22.8	34.1	37.3	45.6	51.9	3.4	1.8	2.0	1.3	1.7
Latin America	8.9	7.7	7.6	9.0	10.2	– 1.2	– 0.4	1.7	1.2	1.1
Africa	2.1	3.8	4.1	5.1	6.0	6.1	1.5	2.2	1.8	1.8
Near East	0.5	0.8	1.0	1.3	1.5	4.3	3.9	2.8	1.9	2.7
Far East	5.3	11.2	12.6	15.6	18.1	6.4	2.4	2.2	1.5	1.9
Asian centrally planned	5.9	10.3	11.5	13.8	15.3	4.8	2.1	1.9	1.0	1.6
Other developing	0.1	0.3	0.5	0.7	0.7	10.7	8.6	3.8	1.0	3.6
Developed countries	24.9	38.4	38.0	39.1	40.6	3.7	– 0.2	0.3	0.4	0.2
North America	4.0	4.1	4.9	6.4	6.9	0.1	3.7	2.7	0.9	2.1
Western Europe	8.9	11.5	11.7	12.5	12.9	2.3	0.1	0.7	0.3	0.4
EEC	4.2	5.3	5.2	5.3	5.5	2.0	– 0.4	0.1	0.4	0.1
Other Western Europe	4.7	6.2	6.5	7.2	7.4	2.3	1.0	1.1	0.3	0.7
Eastern Europe and USSR	4.6	11.3	10.6	9.7	10.0	7.7	– 1.3	– 0.8	0.3	– 0.5
Oceania	0.1	0.2	0.3	0.4	0.6	3.8	8.7	4.8	4.1	5.3
Other developed	7.2	11.3	10.6	10.1	10.2	3.8	– 1.3	– 0.5	0.1	– 0.4

[a] 1963 = average 1961-65.
[b] 1975 = average 1974-76.

represent about 6% of total world finfish supplies, a proportion which is expected to increase over the next two decades.

Future trends in supply

The state of world fishery resources described above provides the framework for the projections of fish supply shown in Table 3. The slow overall growth rate – essentially a continuation of the trend in the 1970s – results from conventional marine finfish, which account for about 75% of the total production of living aquatic organisms, offering relatively poor prospects for increased catches. The situation is relatively more favourable in the developing countries where lightly exploited resources are somewhat more abundant than in the developed countries where technological innovation has led (with some exceptions) to the earlier heavy exploitation of stocks in adjacent waters.

Even within the developing countries, however, given a projected rate of population increase of over 2%, the rate of growth of production will be inadequate on average to maintain per capita levels of supply, notwithstanding the possibilities of diverting to direct human consumption some of the catches now used for reduction to meal and oil. Countries where significant declines in per capita consumption could occur include some of the least developed countries (LDCs), eg Mali and Chad, which depend on heavily or moderately heavily exploited flood plain fisheries and where the expansion of aquaculture is likely to do little more than offset the effect of possible interference with the aquatic environment.[5]

Other developing countries with fairly low projected growth rates include those whose distant-water (or at least non-local) operations will be affected by the establishment of exclusive economic zones (EEZs). The latter are the offshore areas extending to a distance of 200 miles in which the coastal state has sovereign rights for exploiting the natural resources and thus the right to exclude the fishing vessels of other nations. Adjustment to an ocean regime of EEZs arising from the Third UN Conference on the Law of the Sea (UNCLOS III)

[5] Also, in Uganda and Burundi the lake fisheries are already fairly heavily exploited and the prospects for significant growth are not good.

Table 4. Estimated demand for fish 1980, 1990, 2000 (in live weight equivalent)

	Total (million tons)				Feed (million tons)		Food (million tons)				Food (kg/per capita)			
	Consumption	Projected demand			Consumption	Projected demand	Consumption	Projected demand			Consumption	Projected demand		
	1972-74	1980	1990[a]	2000[a]	1972-74	1980	1972-74	1980	1990	2000	1972-74	1980	1990	2000
World	67.2	83.4	78.8	97.1	17.8	23.0	49.9	60.4	78.8	97.1	13.1	13.9	14.9	15.5
Developing	25.5	33.1	42.6	56.7	2.6	3.8	22.8	29.3	42.6	56.7	8.4	9.3	10.6	11.5
Latin America	3.5	4.6	4.2	6.0	1.2	1.7	2.4	2.9	4.2	6.0	7.7	7.9	8.8	9.8
Africa	2.7	3.4	5.0	7.3	0.1	0.1	2.6	3.3	5.0	7.3	8.2	8.7	9.6	10.8
Near East	0.7	1.1	1.2	1.9	0.2	0.3	0.6	0.8	1.2	1.9	3.1	3.6	4.3	5.1
Far East	9.5	12.4	16.0	21.6	1.1	1.4	8.4	11.0	16.0	21.6	8.1	9.1	10.0	11.1
Asian centrally planned countries	9.1	11.5	16.0	19.6	0.2	0.3	8.9	11.2	16.0	19.6	10.1	11.4	14.2	15.4
Other developing	0.1	0.1	0.2	0.3	0.0	0.0	0.1	0.1	0.2	0.3	23.0	24.7	28.1	31.2
Developed	42.2	50.3	36.3	40.4	15.2	19.2	27.0	31.1	36.3	40.4	24.5	26.6	28.5	29.6
North America	5.5	6.2	4.9	5.7	1.8	2.0	3.7	4.2	4.9	5.7	15.7	16.7	18.0	19.4
Western Europe	13.6	15.1	8.2	9.1	6.7	7.8	6.9	7.3	8.2	9.1	19.1	19.7	21.4	23.1
EEC	8.7	9.6	4.8	5.3	4.5	5.2	4.2	4.4	4.8	5.3	16.2	16.8	18.2	19.6
Other Western Europe	4.9	5.5	3.4	3.8	2.1	2.6	2.8	2.9	3.4	3.8	26.1	26.5	28.8	30.8
Eastern Europe and USSR	11.2	14.5	11.6	13.0	3.4	4.8	7.9	9.7	11.6	13.0	22.1	25.5	28.1	29.6
Eastern Europe	3.1	4.1	2.2	2.6	1.8	2.3	1.2	1.8	2.2	2.6	11.5	15.9	18.7	20.8
Oceania	0.3	0.4	0.3	0.4	0.1	0.1	0.2	0.3	0.3	0.4	14.4	14.4	15.2	16.2
Other developed	11.7	14.1	11.2	12.2	3.3	4.5	8.4	9.6	11.2	12.2	62.1	64.3	66.4	64.8

[a] Excluding demand for meal. *Source*: FAO agricultural commodity projections.

is likely to be a major influence on changes in the pattern of fishing for most of the period to 2000. Within the developing countries, for example, the high growth rates for Argentina and some West African countries demonstrate the possibilities of production from abundant resources which have previously either been relatively lightly exploited or exploited by foreign vessels. Opportunities provided by extended jurisdiction explain also the relatively high rates projected for North America and for Oceania. The projected lack of growth in Europe reflects the fact that the resources in most EEZs are already heavily exploited by the coastal state and few opportunities exist for the development of new fisheries. Implementation of policies with respect to EEZs will have little impact on the total catch, although in the short to medium term it is likely to depress yields as coastal states in many areas take action to protect their newly acquired resources.

Future trends in demand

Notwithstanding the sharply reduced rate of growth in production, the forces influencing demand, particularly population and income, are expected to continue to grow at about historical rates. Table 4 shows the estimated growth in demand for fish, which indicates that, on the basis of present trends and the assumption of constant relative prices, global demand to the end of this century will increase at about 3.3%, a rate comparable to an estimated annual growth in production of 1%.

Demand for fish has two distinct components: that for direct human consumption, and derived demand which operates through demand for fishmeal. Potential demand for both is expected to increase – that for fishmeal marginally more rapidly than for direct human consumption. As already indicated, demand for meal is dependent partly on demand for protein feeds, although the relative share of meal in these feeds can vary considerably with price. The estimate for 1980 shown in Table 4 is based on an assumption of constant relative usage; although this represents a reasonable rule of thumb over relatively short periods, long-term problems of supply of fish for reduction to meal and oil (consequently causing a rise in relative prices) make it unrealistic to quantify demand beyond 1980.

The fishmeal market, however, seems to have suffered permanent damage because of the shortages and very high prices which followed the collapse of the Peruvian anchoveta. Compounders are now less keen to include fishmeal in their feeds, although they would if price advantages became marked. This seems unlikely to occur because higher prices are probably necessary to bring new sources of supply under production. Higher prices, however, will encourage the greater use of substitute ingredients in compound feeds. Thus relaxation of the constant relative usage assumption suggests that fishmeal will, with the passage of time, play a diminishing role in the preparation of compound feeds.

Projection of demand for fish for direct human consumption, although still speculative over a period as long as 25 years, can be made with a little more confidence. By 1990, for example, on the basis of present trends and 1975 relative prices, it is estimated that demand will have increased by about 18 million tons over 1975, and that by the end of this century the increase in demand (again over 1975) will be about 30 million tons. Much of the increase will take place in the developing countries (about 75% of the total increase by 2000), largely because of the greater rate of population increase.

Per capita consumption is also expected to increase more rapidly in the developing countries than in the developed world, but the position in this respect is heavily influenced by the Asian centrally planned countries, where an above average rise in income is expected to produce an increase of 5 kg in demand over the last quarter of this century. Elsewhere in the developing countries, growth in per capita consumption is more modest – projected not to exceed 2-3 kg in most regions.

Even increases of this magnitude, however, may prove difficult to attain because even on a relatively pessimistic trend assumption the demand for fish for human consumption, if satisfied, will by 1990 leave only about 5 million-6 million tons available for fishmeal compared to about 18 million tons at present. However, to enable significant quantities of fish now used for reduction to meal to be utilized for direct human consumption presupposes a major R&D programme aimed at converting large volumes of small pelagic fish into acceptable low-cost products. The situation will undoubtedly be more serious by the end of this century when the demand for fish for direct human consumption alone (excluding the possibility of any utilization for meal) will exceed the realistically foreseeable catch.

On a regional basis some adjustment can take place through trade. The creation of EEZs is likely to affect the pattern of trade as much as it affects the pattern of production. In particular, the gradual closing of the option of distant-water fishing as a means of supplementing domestically caught fish is likely to oblige a number of major fish-consuming countries to purchase fish from abroad through normal commercial channels. Offsetting this trade-creating effect, however, is the possibility of import replacement, whereby importing countries acquire jurisdiction over types of fish from which products similar to the imported ones can be made. In addition, some decline in exports can be expected from those countries with distant-water fleets which were also exporters but which will either not now have the fish to export or will divert exports to the domestic market.

The net effect of EEZs, however, is likely to be trade creation; world trade in fishery products is likely to grow more rapidly than production generally constrained by resource limitation. The greatest potential demand for additional imports is in the developed countries, eg Japan and the EEC, and could be met to a significant extent by exports from other developed countries, eg Canada and Norway, but supplies are increasingly likely to come from developing countries, eg Argentina and other South American countries. By the end of this century, however, some developing countries will themselves have substantial import requirements not only to meet increased demand but also, in some cases, to maintain existing levels of consumption.[6]

Only part of the growing supply–demand imbalance at the world level will be resolved by trade, however, and some rise in the relative price of certain types of fish in certain areas seems inevitable. The most rapid rises can be expected in the price of those commodities whose supply, because of resource constraints, is most inelastic. This group includes most crustaceans, salmon and prime demersal fish, but it will, by the 1990s, include also many fish consumed predominantly in developing countries, eg freshwater fish in Africa. Although in theory a rise in price offers opportunities for trade, in practice the

[6] Among these countries are some with sizeable populations, eg India, Bangladesh and Egypt, and some likely to experience serious difficulties in meeting demand for other forms of animal protein, eg Ghana, Ivory Coast and again India.

possibilities are likely to be at least partly limited by transport and other costs and the heterogenous nature of fishery products which imposes some limits on substitutability.

Actions for development and rational management

I have discussed above the most likely trends in world fisheries to the end of this century. Insofar as it is possible to generalize from these, the main issues of concern to many national policy makers will arise from the growing shortage of fish. Appropriate actions to meet this challenge can be broadly classified as follows:

- efforts to increase production either of those conventional species remaining unexploited or of unconventional species or through aquaculture;
- improved utilization of fish now caught, ie reduction of post-harvest losses;
- attention to the problems of management to ensure that already exploited resources continue to provide the desired economic and social benefits.

Efforts to increase production

The possibilities and problems of increasing the catch of conventional species have been discussed above. Where there is a need for increased fishing effort this will be brought about in some cases by normal commercial pressures. In other circumstances some form of outside assistance will be required either from national governments, eg incentive schemes, or from international agencies, eg grants, loans or technical assistance. From multilateral sources, in terms of costs at least, the most important projects to be financed will be those concerned with infrastructural investment, eg marine works including new and improved harbours and port facilities. Investment in this field, which has traditionally been the most important area for regional and international bank financing, could be further boosted by the rising cost of fuel and the desirability of establishing fishing bases near to the fishing grounds.

Improved shore facilities, especially communications, will help to reduce wastage and improve marketing prospects. These considerations apply *a fortiori* to small-scale traditional fisheries where often limited marketing opportunities, waste and poor quality result in low returns and give little incentive to fishermen to increase their catches. Without such improvements to the shore-based infrastructure, attempts to improve vessels (ie through motorization schemes) have often failed, because without better marketing opportunities and thus higher prices, motorization merely adds more to costs than to revenues. As indicated, requirements to improve the situation are much the same as for more industrialized fisheries, ie facilities to handle and dispose of the catch, and facilities for the repair and maintenance of small fishing craft.

The pattern of investment in new vessels is complex, but additional vessels would seem to be required despite the excess capacity already existing throughout the world. Additional vessels will be required to exploit opportunities in some recently established EEZs, ie those having unexploited potential or stocks previously exploited by foreign fleets. For technical and economic reasons it will probably not be possible to redeploy as fishing vessels much of the redundant capacity of the former distant-water fleets.

Investment in vessels has largely been the responsibility of the private sector (except, of course, in centrally planned economies) and this will probably remain so. Apart from marketing and infrastructural deficiencies, the main brake on the growth and development of fisheries is usually management and entrepreneurial ability; attempts to force the pace of development where these skills have been lacking have generally met with limited success. Where there are opportunities for investment the ease with which excess capacity can develop has so frequently been demonstrated (and not only in high-income countries) that a programme of vessel construction requires built-in monitoring to assess also the effect on the stocks; further, because of the lag between the decision to construct and the operation of vessels, such a programme should be approached with caution.

Among the unconventional species, greatest progress has been made with krill. Commercial pressures have already resulted in the development of technically efficient methods for its harvesting and processing. Products developed so far, however, are relatively sophisticated and costly, and the possibility of a mass market for krill products is still some distance away. One problem is that the scale of an operation would have to be very large to provide a product which is commercially competitive with other forms of animal protein – this may entail producing krill in greater quantities than most markets could absorb. Attempts to produce and market a subsidized product would, of course, need to be evaluated against other forms of protein production.

Somewhat further away is the utilization of mesopelagic species – the small boney fish distributed widely throughout the world's oceans. R&D work on this group of animals is only now beginning, and although it seems that there are few technical problems involved in their harvesting, the difficulty lies in the development and marketing of suitable low-cost products. The most promising strategy for the commercial exploitation of these fish seems, therefore, to lie initially in the production of fishmeal. In this respect the major requirement is the establishment and operation of a pilot project. In the long term, however, there are good prospects that these fish can contribute in significant measure to human nutrition directly, particularly as they are found in proximity to many countries having nutritional problems.

More immediate prospects of increases in production are offered by aquaculture, which as well as increasing food supplies can make a significant contribution to rural development through raising the income of small farmers. Apart from developing specific aquaculture schemes these objectives can be achieved through introducing fish as an additional crop, or by introducing the rearing of other animals to fish farmers – in both cases recycling waste. These and other techniques for raising the productivity of aquaculture are well known; the problem is to achieve their more widespread adoption.

The conditions for achieving an increase in production from aquaculture are much the same as for agriculture. In almost all countries with a favourable national environment the initial requirement is for organization, that is for some agency (government, parastatal or private) to convince farmers of the benefits of aquaculture, to organize the supply of inputs, particularly fish seed, and assist with marketing. Once the commercial feasibility of a technology or new development has been demonstrated the main requirement is for an extension service which in most countries implies a substantial training programme.

Training at all levels is, in fact, likely to be one of the major long-term constraints on the expansion of aquaculture in most areas. The provision of necessary facilities will clearly require outside assistance. An equally important object of expenditure is the provision of credit. The primary source of financing for small-scale rural aquaculture in most developing countries is public credit schemes, and aid to aquaculture from outside sources can best be channelled through these institutions, which are gradually acquiring expertise in this field. Clearly, however, successful development requires that the availability of credit should not outrun the capacity of the extension services to supervise its expenditure.

Improved utilization

In addition to attempts to increase the total catch, the improved utilization of fish already being exploited requires attention. It has been estimated that as much as 20% of all fish taken from the sea and fresh waters never reaches the consumer; there are thus considerable possibilities for increasing the supply of fish through improved utilization. There are two main situations where waste can be prevented or reduced, namely in the utilization of by-catches of fish caught by shrimp trawlers and by reducing losses of cured fish in tropical countries. Part of the remedy in both cases lies in providing the necessary economic incentives, but an important element in any programme to avoid waste is improvement in the on-shore handling and storage facilities to which reference has already been made.

I discussed above the need for R&D to permit the utilization for direct human consumption of at least some shoaling pelagic fish now used for reduction to meal and oil and of those shoaling pelagic stocks still relatively underexploited. Some progress has been made in this through the development of type B fish protein concentrate. This is a concentrated powder with a fish flavour, to be distinguished from type A which was a pure protein product with no flavour. In contrast to type A, which was a commercial failure, type B has been manufactured and marketed commercially, but the quantities involved have so far been small. The problem remains finding an acceptable product at a sufficiently low cost, which for many markets rules out canning. Present efforts to increase consumption of these fish are directed towards improving the quality of traditional products such as dried and salted fish, as well as longer-range projects concerned with minced fish.

Detailed project-by-project assessments of investment requirements are not available, but some indication of such requirements can be given on the basis of the incremental capital–output ratio. Assuming this to be 4:1 (fishing is generally a more capital-intensive activity than agriculture), net investment requirements in the primary sector would be about $20 000 million with an average price of fish of $400/ton, taking into account that as much as half the projected increase in the world catch is due to management, ie recovery of overfished stocks, which will take up underutilized capacity rather than require new vessels. Total net investment requirements are considerably above this figure, however.

because, as already noted, emphasis needs to be given to improved handling and processing, and thus a figure of $35 000 million would be nearer the true needs. This figure makes no allowance for investment in the harvesting of krill or mesopelagic species in this regard, and in whatever form they will be exploited, and it must thus be regarded as conservative. Gross investment, of course, allowing for the replacement of existing equipment and vessels, could be several times net investment.

Management

Many problems associated with production are likely to be solved only in the medium and long term. More immediate are the problems of ensuring the maintenance of high and sustained yields from already exploited stocks. The management issue is relatively urgent not only because of the new legal regime of the seas – a change which has considerable implications for the mechanisms by which international fisheries are regulated – but also because of the increasing number of stocks requiring management action to restore yields and reduce excessive costs.

Overfishing first became an issue early this century in connection with the demersal fisheries of the North Sea. Despite early recognition of the problem, most attempts at management have not been attended by conspicuous success, and the effects of unrestricted expansion, ranging from declining profitability to complete collapse of a stock, have been repeated again and again; these effects have been observed in fisheries in a wide range of ecosystems and in the context of both single and multispecies fisheries. Present changes in the law of the sea reflect, in part, dissatisfaction with previous arrangements.

In those areas where serious economic distress in the fisheries made some action necessary, these arrangements frequently took the form of international commissions, eg the International Commission for the North-West Atlantic Fisheries (ICNAF). In general this system met with only limited success, but certainly left the stocks in better condition than they would have been without such management. The commissions had a very positive impact on the development of methods for resource evaluation and on the understanding of the various problems of fisheries management. In fact, these bodies were very suitable for the technical aspects of the problem but not for the political aspects related with authority and decision making. Arrangements under an EEZ regime offer the prospect of improvement in the latter by establishing authority and responsibility for resources and their exploitation.

Establishment of sovereign rights in the fisheries in a coastal band of 200 nautical miles, however, will not in itself ensure the satisfactory management of fish stocks – even those occurring exclusively in one national zone – in accordance with national economic and social priorities. Effective management requires satisfactory institutional arrangements including appropriate laws, adequate research capabilities (or at least access to the required information) and the necessary means of surveillance and enforcement. Many developing countries lack at least one of these conditions and many lack all three. Providing support in this field will be a major task of international assistance for the foreseeable future.

New England Fisheries/Aquaculture

Student Activities

1. Locate on the map provided, the current major New England fishing ports.

2. Select three fishing ports and determine the following:
    a. The major species caught,
    b. The Total landed catch,
    c. The value of this catch (in dollars),
    d. Where this catch is processed,
    e. Whether the processor is a local company or part of a large conglomorate; foreign or American,
    f. The distribution area of this catch and the methods of distribution,
    g. The projected goals/concerns of the particular fishing port,
    h. The size of the fishing fleet. Note any existing or expected plans for expanding the fleet and/or port facilities.

3. Select one Massachusetts fishing port and:
    a. Complete the above information
    b. Complete as inclusive as possible an historic review of this fishing port. Include the specific changes that have taken place within this area. Consider such topics as the reliance of the population on the fishing/processing industries, other types of employment in the area, and the general overview and projection for this particular area. Be specific.

N.B. Two good sources for information on the above research questions include:

The Department of Massachusetts Marine Fisheries
The Department of Fish and Game
The Chamber of Commerce for the specific area.

<u>New England Fisheries/Aquaculture</u>

<u>Student Activities: Aquaculture</u>

1. Determine which areas of New England have existing Aquaculture programs. Give a short review of each: dates of origin, the size, kind, production of each area.

2. Give the economic status - the cost effectiveness of this program. Determine whether you feel this could be a growing and viable industry in the USA. To what extent do you think Aquaculture could be expanded within the USA? Is it possible to consider an extensive Aquaculture/Agriculture industry within the USA?

3. Explain the projected plans for the specific industries you have researched.

4. Select one specific type of Aquaculture and give an indepth review and include the following: the species raised, the specific conditions required, particular problems and the methods taken toward their solutions, the economic viability, etc.

Study Questions: Aquaculture in China

1. Comment on the level of fish production in the Peoples' Republic of China. Relate this to other areas of the world.

2. Explain two types of fish management on the Chinese commune.

3. Explain the integration of aquaculture and agriculture that is found on the fish-farming communes in China. (See also the chart on p. 24.)

4. The author notes the data may not be accurate. Given that understanding, comment on the amount of fish production in China.

5. Compare the total fish yields from:
   a. Aquaculture
   b. Marine fish landings (from fishing fleets)

6. What impact would this data have on China? What implications can you see for this information in other areas of the world -- in the USA? In the Third world?

7. Discuss the marine fisheries and processing industries in China. Contrast this with other known areas of the world. What is the impact of this on aquaculture?

8. Explain the organization of aquaculture production in China.

9. Explain the meaning of this statement: "The terrestrial and aquatic farms supplement each other in a number of important ways that increase yields of each component part." Give specific examples.

10. Which specie is most common on the Chinese fish farm? Which fish?

11. Explain the pond ecosystem and polyculture which results in the utilization of agricultural wastes and produces the "... low cost high yield achievements of Chinese pond culture."

12. A major problem that has to be addressed in aquaculture production is that of disease. How do the Chinese communes resolve this problem? Explain the author's comment on this issue.

13. To what extent has China engaged in research programs concerning aquaculture? What are some of the findings and results?

14. What is the level of marine aquaculture in China? What are the most viable marine organisms?

15. Which organism have the Chinese used for selective breeding?

16. What is the status of the mussel, scallop, and shrimp industry in China?

Mariculture:
How Much Protein and For Whom?

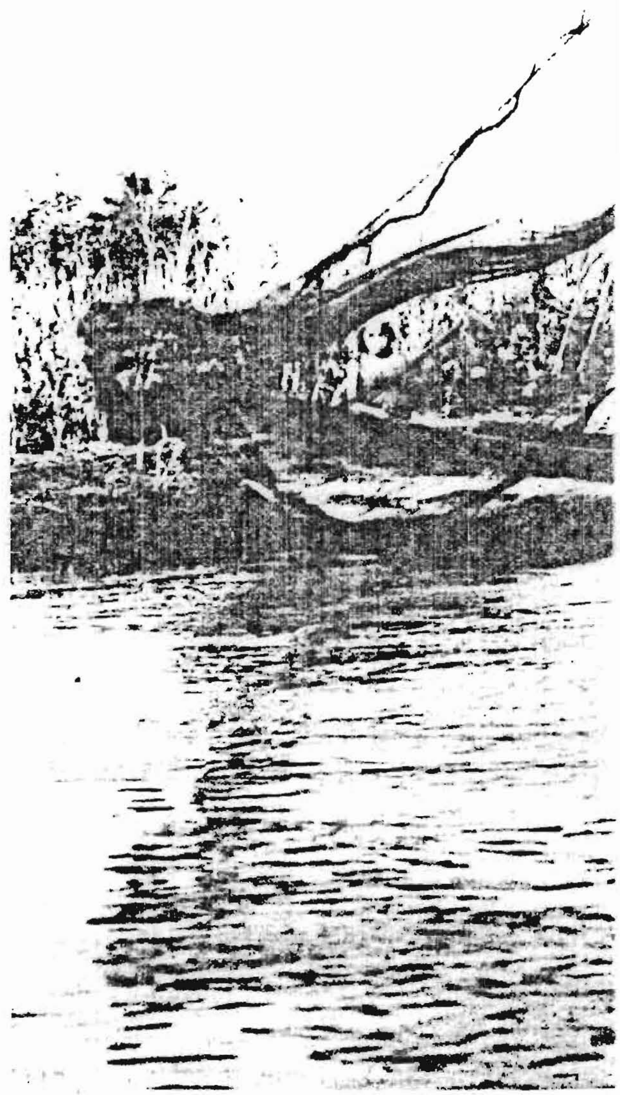
John H. Ryther

Marine aquaculture, or mariculture, is generally looked upon in the Western World as a new concept in food production, an outgrowth of the traditional commercial fishing of natural stocks of marine organisms, a more sophisticated approach whereby fast-disappearing luxury seafoods may be mass produced in intensive culture systems analagous to the feedlot production of cattle or the factory-like modern poultry industry. Often overlooked is the fact that aquaculture, though usually carried out in fresh or estuarine waters, is an old and well-established practice in many parts of the undeveloped world, particularly in Southeast Asia and the Orient, where aquatic organisms have been successfully cultured for centuries. Although these latter practices are technologically unsophisticated, they are surprisingly reliable and productive, and have made a significant contribution, economically and nutritionally, to those parts of the world where they are carried out.

Such, unfortunately, cannot be said for the embryonic mariculture industry of the United States, the rather dismal track record of which threatens the field with extinction before it has fairly gotten under way. What are the reasons for these ill-fated beginnings, and what is the prognosis, here and elsewhere, for marine aquaculture? Before proceeding with such an analysis, let us look briefly at the current state-of-the-art. Who is growing what, where, and how? And even more basic, what kinds of animals can be grown in culture?

Desirable Characteristics in a Cultured Species

To be a suitable candidate for aquaculture, a species must satisfy several basic prerequisites. First, it must be a popular and preferably a luxury food, capable of bringing a high market price. Failing this characteristic, the species must be easy and inexpensive to grow so that, if marketed at a modest price, it can still insure a profit to the grower. It



Farmers in Thailand harvest some of the fish grown as a by-product of rice cultivation. (I. Polunin, Bruce Coleman Inc.)

must grow rather quickly in culture, if possible to a marketable size within a year or less. It must be hardy and adaptable to growth in rather dense culture with a minimum of mortality due to handling and crowding under the unnatural conditions of cultivation. It should be relatively resistant to the diseases and parasites that are normally present in seawater. Its nutritional requirements must be known, and it must be capable of feeding, with a high conversion efficiency (growth: food consumed), upon artificial or natural foods that are readily available and inexpensive. Finally, the species should be capable of being brought to sexual maturity and successfully mated and spawned in captivity—naturally or by artificial manipulation (hormone-induced maturation, stripping of eggs and sperm, etc.)—hatched, and reared through its larval stages to juvenile animals, again without excessive mortality.

The entire propagation and larval development process entails a completely different set of practices and procedures from those involved in "growing out" the juvenile animals to market-sized adults. Once the problems are solved, assuming that the established procedures are carefully and consistently followed, the rearing of animals to the juvenile stage usually becomes routine, and vast numbers can be produced on demand in modest facilities and at relatively low cost. But the biological problems of breeding and larval rearing are often subtle and intractable. As a result, many otherwise desirable species have not yet been grown in captivity throughout their complete life cycle; and post-larval, juvenile animals cannot be produced routinely, if at all. In some cases this problem has been circumvented by collecting juveniles from their natural nursery areas. Although this is typically done in the culture of some species (milkfish in Southeast Asia, yellowtail in Japan), the difficulty and expense of obtaining, on a reliable basis, a sufficient number of juveniles to support a sizable culture operation are constraints that have severely limited the development and expansion of such practices.

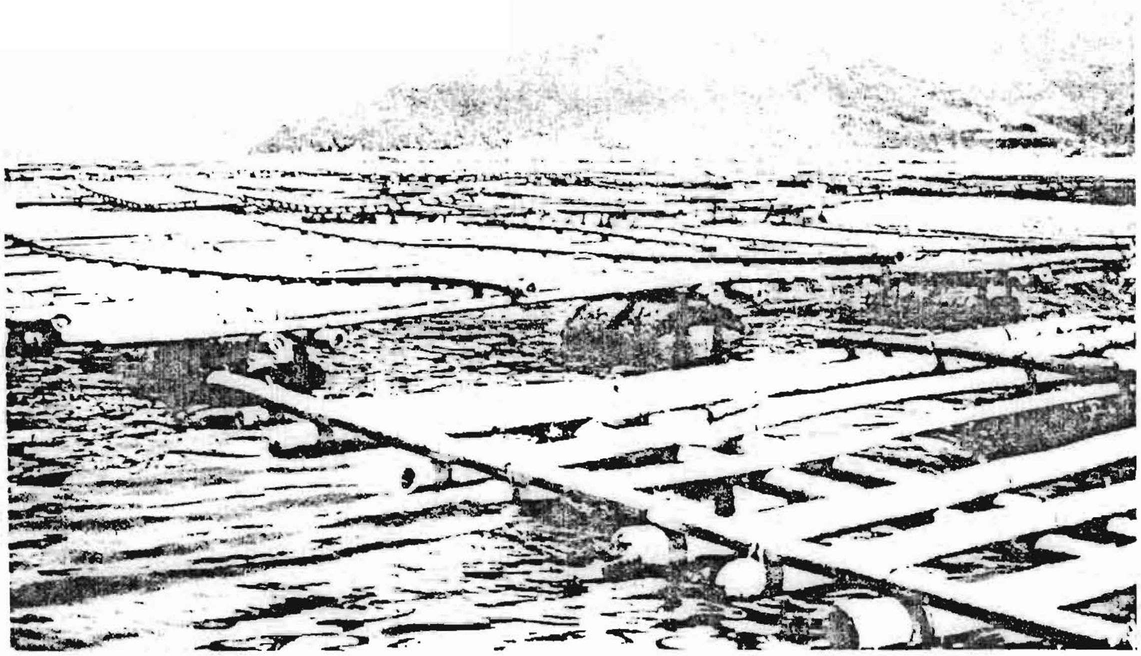
With the above, rather formidable list of prerequisites, it is perhaps not surprising that only a handful of marine and estuarine species have passed the test and are now in commercial culture. These are reviewed briefly below.

Molluscs

The bivalve molluscs represent a rather special case. Following the pioneer work of W. F. Wells of New York State during the 1920s and the subsequent efforts of V. L. Loosanoff (NMFS, Milford, Conn.) and T. Imai (Japan), first oysters and then many species of molluscs—including clams, scallops, and mussels—have been routinely spawned and reared through their larval stages to juvenile or "seed" shellfish in commercial hatcheries. (One of the few innovations in aquaculture that originated in the United States, shellfish hatcheries are now established around the world.) However, except for a few experimental attempts, no one has yet reared the newly set "seed" to market-sized adults in a controlled, artificial grow-out system, due largely to the difficulty and impracticality of producing a sufficient quantity of the unicellular algae or other microorganisms upon which the bivalves feed, or of finding a suitable artificial food. Instead, the hatchery-produced juveniles are grown to market size in natural environments (bays, estuaries, or protected coastal waters), on the bottom or sometimes in or on trays, racks, strings, or other devices to suspend them off the bottom. The role of the hatchery is thus to supplement or replace natural reproduction or to provide juvenile animals for stocking and colonizing new areas.

The cultivation of oysters and mussels is one of the world's oldest and, overall, probably the most successful form of mariculture. It ranges in complexity from the very simple practice of harvesting natural populations—actually a form of commercial fishing that can hardly justify the term "culture"—to the highly sophisticated and intensive raft culture of oysters in Japan and of mussels in Spain. Intermediate are those enterprises, notably in the United States and Europe, where seed shellfish—hatchery-reared or collected from nature by various means—are planted, tended, moved about, and otherwise cultivated in specially designated and usually privately controlled growing areas.

Whatever the culture method, the bivalves feed upon the plankton algae that are normally present in the seawater, and there is no attempt to control or improve upon the quality or rate of production of this natural food. Nevertheless, yields from shellfish culture may be impressive, ranging from 10 to over 1000 metric tons per acre per year of pure meat (shells excluded) in the more successful raft-culture practices. Such yields are made possible by the fact that food, in the form of suspended phytoplankton, produced over an area several orders of magnitude greater than that involved in the shellfish culture, is brought to the molluscs by the tides, currents, and other water movements; and the animals thus serve as a convenient and highly efficient concentrator and integrator, within a small area, of the organic



In raft culture, seed oysters attached to scallop or oyster shells are strung on wire or rope and suspended from rafts. (Top) Bamboo oyster rafts buoyed by hollow drums. (Bottom) Intensive oyster culture in Kesennuma Bay Japan, where there are more than 5000 rafts. (J. H. Ryther, from J. E. Bardach, J. H. Ryther, and W. O. McLarney, Aquaculture, *Wiley, 1972)*

matter produced over a large region.

The only other mollusc that is a serious candidate for aquaculture is the abalone—highly prized, highly priced, and rapidly disappearing from natural fisheries throughout the world. Readily amenable to the same hatchery-rearing techniques as oysters and other bivalves, young abalone can be produced in very large numbers at low cost, but as many as five to seven years are required for the juveniles to reach a marketable size. They must somehow be provided throughout that period with a steady and rather large supply of the right kinds of seaweeds upon which they naturally feed. Thus, commercial abalone culture has been attempted but has yet to succeed beyond the practice, by government laboratories in Japan, of stocking "seed" animals in natural growing areas, much the same as is done with oysters and other bivalves in the United States.

The other major group of molluscs, squid and octopus have been grown experimentally in the Far East, where they are highly regarded; but, so far as is known, not on an established commercial basis.

At the NMFS Experimental Shellfish Hatchery, Milford, Connecticut, clams and oysters are induced to spawn out of season (top); juvenile clams, in a controlled grow-out system, are fed cultured algae (center); and on the "tank farm," post-set oysters are grown out, and algae mass-cultured (bottom). (NMFS, Middle Atlantic Coastal Fisheries Center, Milford Laboratory, Milford, Conn.)

Seaweeds

A practice somewhat analogous to mollusc culture is followed in Japan and perhaps a few other Far Eastern countries, where certain species of seaweeds are grown and marketed as a luxury food (nori, aonori, wakami). Many of these algae have complicated life cycles, with an alteration of generations involving two quite dissimilar life forms—the large conventional seaweed that is eaten, and a much smaller, near-microscopic form that produces the spores from which the seaweed grows.

The complete life cycle of some species of commercially important seaweeds has only recently been understood and described. There are now small culture facilities throughout Japan where the spore-producing plants are cultivated. Usually operated by the prefectural governments or fishery cooperatives, these laboratories maintain the algae until their spores are released, at which time the local growers, for a nominal fee, immerse into the culture system string-mesh nets, ropes, or other devices to which the spores attach. These are then planted out in estuaries or protected coastal areas, attached to wooden frames, hung from longlines, or otherwise suspended, where the spores then grow to the edible seaweed form.

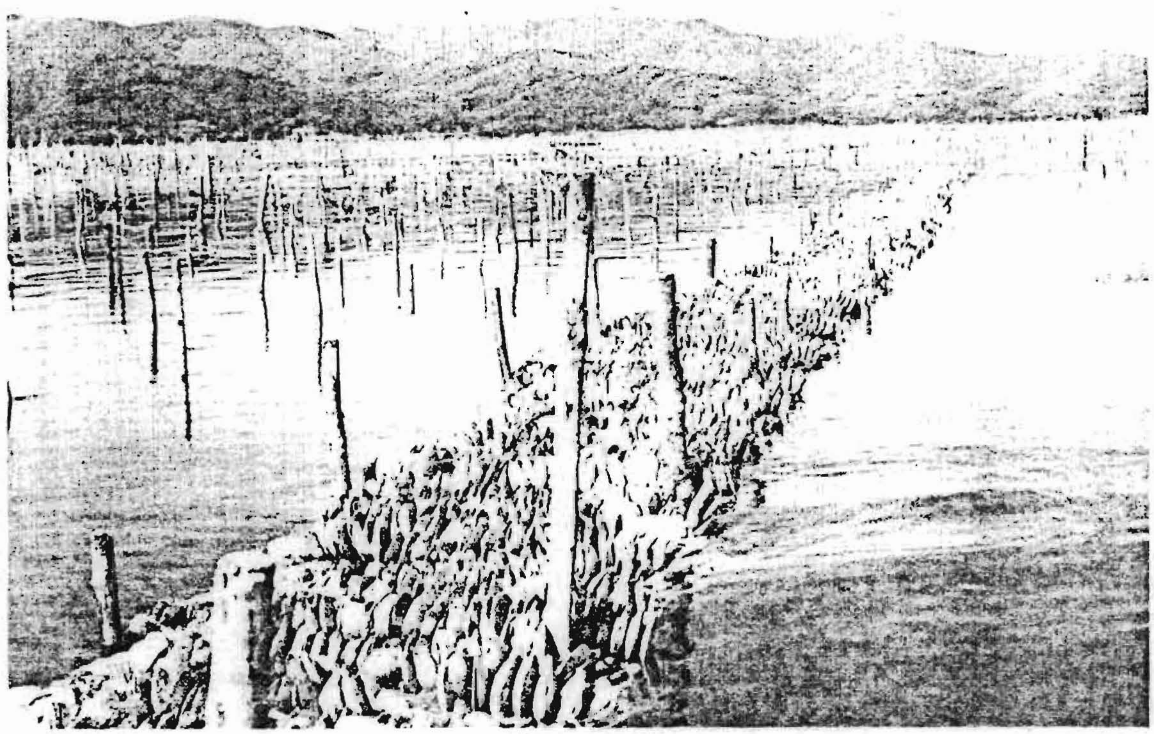
Crustaceans

Among the crustaceans, indeed of all marine organisms, the penaeid shrimp (or prawns) are the most popular target for aquaculture, due in large part to their universal popularity, high price, and almost unlimited market potential. The initial breakthrough in shrimp culture was achieved in 1934 by the Japanese fishery biologist Motosaku Fujinaga, when he successfully spawned and hatched the eggs of *Penaeus japonicus* ("kuruma" shrimp in Japan) from gravid females and reared the larvae through their several stages to juvenile shrimp. As mentioned above, once this stage was accomplished and perfected, the hatchery production of post-larval shrimp soon became routine and is now widely practiced in commercial, government, and academic institutions throughout the world. All of the popular food species from the Southeastern and Gulf coasts of the United States (pink, white, and brown shrimp) are now hatchery-reared in various U.S. aquaculture facilities, and other possibly better-suited species from elsewhere in the world are being tested.

The one phase of the life cycle of shrimp that has thus far eluded hatchery manipulation, at least as an established practice, is the bringing of adult shrimp to sexual maturity, egg production, and mating in captivity. Gravid, fertilized females must still be obtained from the commercial fishery and brought into the hatchery, where spawning and hatching may then be readily induced, almost on demand. This limitation may represent a rather serious constraint to a large aquaculture operation, particularly if a year-round commercial shrimp fishery is not operative near the hatchery. The post-larval shrimp may be grown to adults in a number of ways: in ponds, cement raceways, fenced-off portions of embayments, etc. One of the most attractive attributes of shrimp is their ability to reach a marketable size in as little as four to six months, given proper and adequate food and optimal temperatures, salinity, and other environmental conditions. Two and even three crops a year can, at least theoretically, be grown in some parts of the world.

Modern shrimp farming usually involves growing the animals in dense culture, stocking up to 100,000 post-larvae, with projected yields of 10 tons or more per acre. Shrimp are omnivores and eat a wide variety of living and dead plant and animal material; but no natural system can provide the food for such densities, and they must therefore be fed extraneously. In Japan a variety of natural foods are used: ground whole fish, molluscs, even shrimp taken in the commercial fishery but too small

Scallop shells are used to collect "spat" in a seed oyster farm in northeast Japan. The free-swimming larvae metamorphose, settle on a solid object, such as a shell, and remain sessile for the rest of their lives. (J. H. Ryther, from J. E. Bardach, J. H. Ryther, and W. O. McLarney, Aquaculture, *Wiley, 1972)*



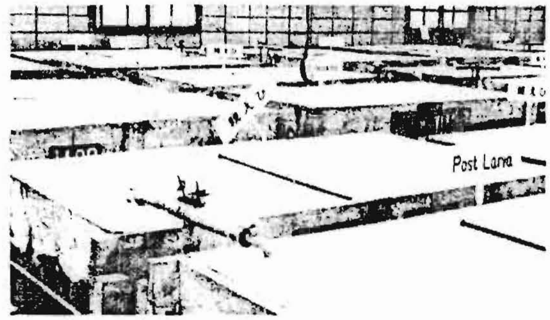
for the market. The high price of this food and of the associated labor and other operating costs is at least partly compensated by the fact that prime kuruma shrimp, marketed alive for the tempura restaurant trade, brings as much as $10/lb to the grower. In the United States, where seafood prices have not yet reached this level, such costs would be prohibitive, and emphasis has been placed on the development of inexpensive artificial feeds and more mechanization of the culture operation, thus far without significant commercial success.

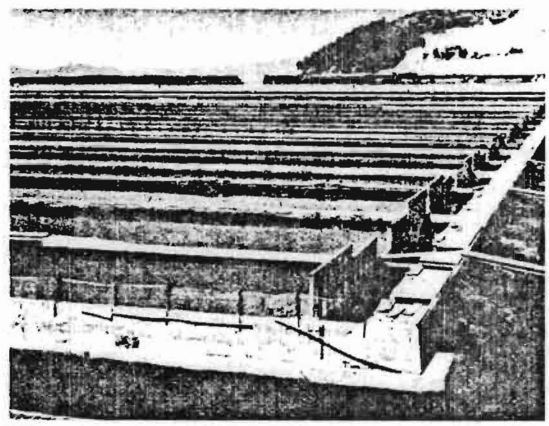
The other marine crustacean that has long been eyed by aquacultural entrepreneurs as a species of enormous market potential and very high value is the American lobster (*Homarus americanus*). Unlike shrimp, lobsters are rather easily carried through their complete life cycle in captivity, eliminating dependence upon egg-bearing females obtained from the commercial fishery.

In their natural environment of Eastern Canadian and New England coastal waters, lobsters require five to seven years to reach a marketable and legal size of about one pound, but they will attain the same growth in culture in two years or less if maintained at their optimum temperature of about 20°C.

Lobsters, however, are cannibalistic by nature, and freshly molted individuals fall prey to their own species if they are not physically protected from one another. They are territorial by nature and do not readily adapt to the crowded conditions that many other species accept in culture. And a successful artificial feed has yet to be developed. Although these problems are not insurmountable, the economics of growing, feeding, and caring for large numbers of individually compartmentalized lobsters and of maintaining them at their optimal temperature for as long as two years has thus far discouraged potential culturists from any serious commercial venture with the species.

The clawless cousin of the American lobster, the spiny lobster (sometimes also called crayfish, but not to be confused with the small, freshwater crustacean) includes many tropical and semitropical species that range throughout the world. Although they are also valuable food species, none has yet been reared through its long and complicated larval development. There has been speculation on the possibility of collecting young spiny lobsters from the wild and growing them to market size in captivity; but they are not abundant or particularly easy to catch in quantity, and the matter has not been pursued.





Shrimp farming facilities in Takamatsu, Japan. (Top) Tanks for rearing larvae. Each 250-gallon tank, heated and filled with filtered seawater and air, can accommodate 15,000 larvae. The building has a greenhouse roof. (Bottom) Cement raceways in which post-larval shrimp are grown to adults. Seawater is pumped through each 10-by-100-meter raceway. (J. H. Ryther, from J. E. Bardach, J. H. Ryther, and W. O. McLarney, Aquaculture, *Wiley 1972)*

Finfishes

The other major group of cultivated marine organisms is the finfishes. This includes a somewhat greater variety but still a surprisingly small number of species. Of these, the salmonid fishes (trout and salmon) are the most popular and widespread in their use, with almost universal acceptance as a luxury food. These are anadromous species that spawn and spend the first part of their lives in freshwater, where they can also remain and grow to maturity.

Freshwater trout culture is among the oldest and most highly developed forms of aquaculture in the Western World, originally carried out for the purpose of stocking natural waters for sports fishing. Only recently have these species been grown directly for human food. After some initial growth in freshwater, most trout can be readily acclimated to salt water, though not all are anadromous in nature. Rainbow trout in particular have proved a successful species for mariculture in such widespread countries as Japan, New Zealand, Scotland, Norway, Denmark, United States, and Canada. More recently, both Atlantic and Pacific species of salmon have become popular substitutes for trout, having much the same requirements and characteristics in culture, but commanding a significantly higher price on the market.

Because of the long history of salmonid culture, controlled spawning, larval rearing, and juvenile development (all in freshwater) have become commonplace. Grow-out to whatever size is desired for market (half-pound to one-pound "pan size" salmon is an interesting new product in this field) is also not difficult, though disease is a persistent problem with these species. A variety of pelletized, artificial feeds are commercially available and used with varying but generally good success.

Salmonids are active fishes with a high metabolism and, in dense culture, require a rapid exchange of water for oxygen replenishment and waste removal. Culture systems include raceways, ponds, impoundments of various sizes and shapes, and net cages, which may be suspended in protected inshore waters. The latter have the advantage that natural currents and tidal action provide the water exchange without the need for costly pumping, a benefit that may, however, be offset by the vulnerability of such structures to weather, tides, predators, and other factors and by their relative inaccessibility to feeding and maintenance.

In short, the biology and technology of salmonid fish culture, though not without some remaining, persistent problems, are well developed; it is primarily the economic factors that decide the success or failure of a mariculture operation. Such is not the case with other, truly marine species of finfishes, most of which have never been successfully cultured anywhere and none of which are now commercially reared in the United States. The one local species that has come closest to utilization is the pompano, a tropical to semitropical fish highly regarded in selected areas of the Southern United States, where it is commercially landed, and probably with considerable, if limited, potential for an expanded market. Pompano, like many marine fishes, have small and delicate eggs and larvae that are sensitive and difficult to handle, feed, and grow. Until very recently, the species has resisted attempts at their artificial spawning and larval rearing; and pompano culture efforts, centered in Southern Florida, were dependent upon collecting wild fry from along that coastline, a practice that could not sustain any substantial culture operation. One company has now made the critical breakthroughs and can routinely produce juvenile pompano on demand from its own brood stock, providing not only independence from the wild stock but also the means for genetic selection and improvement of the species specifically for characteristics desirable for culture. Commercial pompano culture is therefore now a distinct possibility, but not yet economically a reality.

*(Top) Egg-bearing female American lobster (*Homerus americanus*). (Bottom) Third-stage American lobster larvae, about eight days old. (Gareth W. Coffin, NMFS, Biological Laboratory, Boothbay Harbor, Me.)*

Only in Japan, where a variety of marine life is avidly consumed, has mariculture developed to the stage where several species of finfishes are commercially grown. Most of these, however, are freshwater species, as is true elsewhere in the world. The list of cultured marine fishes is still short but includes, in addition to the ubiquitous salmonids, yellowtail (a scombroid fish related to the amberjack), puffers (a great delicacy in Japan), both black and red porgies, and a few others including tuna, now being reared experimentally.

Yellowtail has not yet been propagated in captivity, but a separate and carefully controlled industry exists for the collection of fry from the wild and their rearing to juvenile fish ready for stocking in the net cages that had their origin and have been very successfully employed in this form of mariculture. Both fry and adults are fed ground waste fish, shrimp, and other natural seafoods, but increasing use is now being made of artificial feeds.

Although highly labor intensive and costly (a factor again offset by the high price of luxury seafoods in Japan), yellowtail culture must be considered one of the most successful examples of intensive mariculture in the world today. Carefully regulated and supervised, the industry produced over 30,000 metric tons of fish in 1968, and only restrictions on the numbers of fry allowed to be taken from the wild stock has prevented much greater production. Significant expansion of the industry will undoubtedly occur when and if controlled reproduction of the species is achieved.

Fish Farming

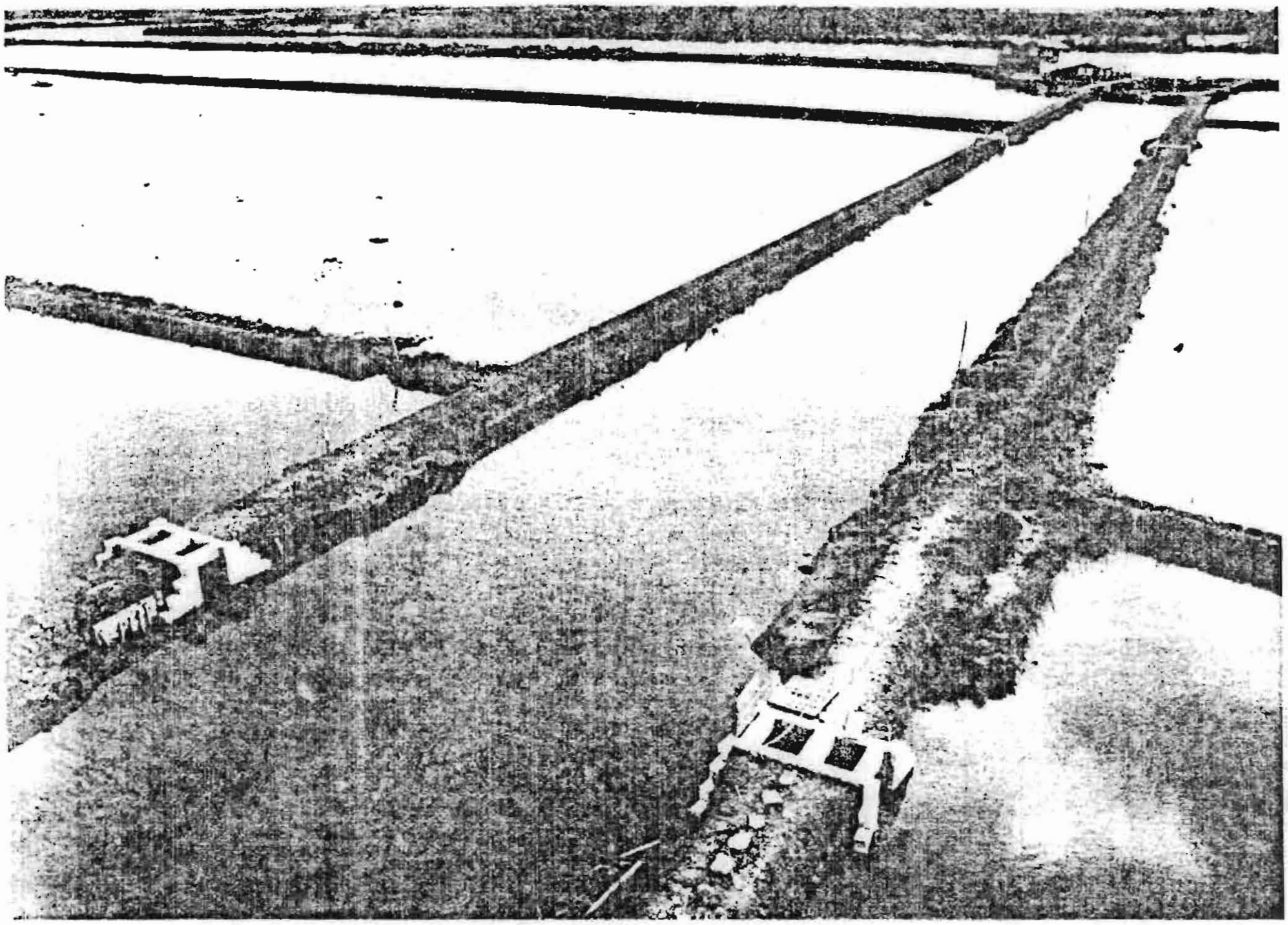
Thus far, only high-priced, luxury seafoods have been discussed here—species grown for the most part in the wealthier, developed countries of the world where profit is the only motive for aquaculture. The contribution of such culture to the particular country's food supply is incidental and almost negligible, besides being well beyond the economic reach of any inhabitants who may suffer from protein deficiency. This, however, is not the case everywhere. As mentioned earlier, fish farming has been successfully practiced for centuries in parts of Southeast Asia and the Far East, particularly Mainland China. Most of this kind of aquaculture is done in freshwater ponds, but there are also some marine species that are widely used in estuarine, brackish-water culture. They include the mullets, of which there are several species, and the milkfish, both of which are distributed throughout the world's tropical and semitropical latitudes.

Both mullet and milkfish are extremely hardy and adaptable fishes that can tolerate, among other things, salinities ranging from pure freshwater to full seawater. They are popular food fish in most places where they naturally occur or are grown. Most important, they are among the few edible finfishes that are predominantly herbivorous, or omnivorous, feeding largely on filamentous algae, dead organic matter, and the many small animals that live associated with the mats of algal material in brackish ponds and estuaries.

Recent advances in Israel, Taiwan, Hawaii, and elsewhere have now made it possible to bring mullet to sexual maturity and to spawn them artificially, through use of pituitary hormone injection, though this is not yet standard practice in mullet culture. Artificial propagation has not yet been accomplished with milkfish, and it is suspected that the species is not normally grown in captivity to the size and age at which it normally matures sexually. At present, the fry of both species are collected from natural nursery areas and, as with Japanese yellowtail culture, there is often a separate industry involving their collection and cultivation to juveniles ready for stocking in grow-out ponds.

Probably more mullet are reared in fresh than in salt water, but significant quantities of mullet and most milkfish are grown in shallow marine to brackish-water ponds, usually constructed from coastal mangrove swamps. Because of their low position on the food chain, these fish do not need to be fed extraneously with natural or prepared feeds, but simply forage on the natural algal populations and the associated living and dead flora and fauna. The mats of filamentous algae, which are called "lab-lab" in the Philippines, are often specially prepared and cultivated in the ponds by various, rather simple methods; and they may be encouraged by modest fertilization, usually with green manure. But one of their principal constituents are filamentous blue-green algae, which have the ability to fix atmospheric nitrogen and thereby reduce or eliminate the need for providing that scarce and costly ingredient.

Because there is no extraneous feeding and, for that and other reasons, very little labor required in this kind of aquaculture (except for stocking and harvesting, a single watchman is the sole requirement for maintaining several hundred acres of ponds), operating costs are very low. Yields also are low relative to those that may be obtained under the best of conditions in intensive raceway, pond, or cage culture with heavy feeding; but one-half-pound milkfish can be grown in about six months, and yields on the order of one metric ton



Aerial view of brackish-water milkfish ponds in the Philippines. White structures are sluice gates; bamboo screens filter the water entering the ponds from the estuary. (P. Boonserm, FAO)

per acre per year are common, a production that is impressive by any standard for high-quality animal protein.

Thousands of acres of brackish-water milkfish ponds have been constructed from the mangrove-lined coasts of Taiwan, Hong Kong, Philippines, Malaysia, Indonesia, and neighboring countries. Together, their annual yield is in excess of a quarter of a million metric tons of this popular food fish. Equally important, because of the simplicity and low operating costs of the culture method, the fish may be marketed at profit at a relatively low price that is within reach of the average consumer of those countries.

Problems with Intensive Mariculture

With the above background, let us now return to the status of modern intensive marine aquaculture, as typified by the general approach that has been taken in the United States, and consider some of the problems that have beset this new field. Much of the difficulty must be attributed to the ambition, impatience, and naïveté of the aquacultural entrepreneur. The cliché of learning to walk before trying to run is nowhere more appropriate, but venture capital is not often available for small pilot projects, or slow, deliberate progress. The experience of rearing dozens to hundreds of animals in the laboratory, at the level of a basic research project, is too often extrapolated to a large commercial operation involving millions of animals, in almost complete ignorance of the biological, technical, and economic problems of scaling.

Coastal wetlands are becoming scarce and costly. Often they are unavailable in large tracts, or their use is severely restricted. It has been well documented that many species of fish can not only live but also grow normally when packed together literally like sardines in a can, if enough food and water are pumped through the container. So the temptation is strong to emulate the cattle feedlot system: condense the aquaculture operation into a small and manageable fish factory rather than turn the animals loose in extensive and expensive grazing areas, and let technology provide for their care and feeding.

The ecological problems encountered in such highly intensified mariculture may be formidable. Disease, always the nemesis of animal breeders, is a far greater problem in the aquatic medium where, in contrast to terrestrial situations, the spread of pathogens from infected to uninfected individuals is virtually impossible to prevent. The incidence and spread of disease is directly proportional to the density of the animals, not so much because their proximity facilitates transmission but, probably more important, because crowded animals are frequently, if not always, in a condition of physiological stress, which makes them particularly vulnerable to the onset and effects of diseases. In addition to the usual bacterial and viral infections to which aquatic animals are subject, various parasites are also readily transmitted in the aquatic medium and may seriously affect survival, growth, and condition as well as the appearance and marketability of the product.

Aquaculturists sometimes claim conversion efficiencies approaching 1:1 – that is, one pound of food is required to produce a pound of the cultured animal. This is an apparent ecological impossibility, among other things defying the second law of thermodynamics, but results from the fact that, under the best of conditions, one pound of essentially dry food can be converted to a pound, fresh weight, of fish that consists of some 80 percent water—an actual efficiency of about 20 percent. In practice, this is seldom if ever achieved: efficiencies of 10 percent or much less are the rule. Thus, the grow-out of a million pounds of fish in a year or less requires an input of between one and ten million pounds of food, most of which either is not eaten in the first place or is defecated or excreted back into the system as both dissolved and particulate wastes. The organic content of these wastes has an exceedingly high oxygen demand, particularly at the relatively high water temperatures (15-25°C) usually preferred by culturists for rapid growth. Some of the wastes, such as ammonia and its intermediate oxidized form, nitrite, are highly toxic. Finally, the organic wastes provide an ideal substrate for disease organisms and exacerbate that problem.

For all of the above reasons, the wastes and uneaten food must be quickly and efficiently removed from the culture system. Rapid water exchange, with retention times of minutes to a few hours at most are essential in dense culture systems. Solid wastes that do not flush out with the normal flow of water must be removed by mechanical means or, often, by hand labor. Even the most ingenious self-cleaning techniques usually cannot prevent the growth of fouling organisms—bacterial slimes, algae, various invertebrate species—on the bottoms and sides of the culture system. Thus, no matter how efficient and effective the mechanization, considerable hand labor appears to be an inescapable requirement.

Flushing of the wastes from an intensive aquaculture system simply transfers them elsewhere in the environment. Aquaculture is therefore a significant source of pollution. It has been estimated that the wastes of about 10 pounds of hatchery-reared trout are equivalent to those of one human. A million-pound culture facility produces the same kinds and quantities of wastewater as a city of roughly 100,000 people. Discharge of such wastes into estuaries or coastal waters is not only undesirable but, under present regulations, illegal without the same degree of treatment as required for domestic human wastewater.

Economically, the problems of intensive mariculture are no brighter. The equipment and machinery for handling or even for occupying large volumes of seawater with adequate protection and minimum risks from corrosion, fouling, weather, etc., are extremely costly. Capital outlay for a major mariculture facility, whatever the configuration or method of culture, can easily run to millions of dollars. Operating costs, particularly where pumping large volumes of water is involved, but also including the inevitable labor requirements, are also high.

But the single greatest cost of intensive mariculture is usually that of food. Typically, the prepared pelletized feeds now in use consist of mixtures of animal and vegetable meals and oils, fortified with mineral and vitamin supplements. Requiring a high and complete protein content for rapid growth, such feeds usually contain a significant proportion, as much as 25 to 50 percent of fish meal.

Commercial feeds generally range from one to ten cents per pound. At low conversion efficiencies, of the order of 10:1 at the high end of the price spectrum, the culturist has an investment in food alone of about $1.00 per pound of his product—an uneconomical practice at the outset. Commercial culturists can and must do much better than this, but food still normally accounts for 25-50 percent of total operating costs. And, while the price of luxury seafoods is rapidly escalating, the cost of feed may be climbing even more rapidly. The recent failure of the Peruvian anchoveta fishery, the major source of fish meal in the world, more than doubled the cost of that commodity during 1971-72, leaving the aquaculturist with the dilemma of absorbing the increase in his already prohibitive operating costs or going to less desirable food ingredients that result in poorer growth and lower conversion efficiencies.

Finally, the provisions of the new Federal Clean Water Act and Amendments, forcing the mariculture industry to subject its effluents to sophisticated wastewater treatment, if enforced, will provide a new cost factor that could bankrupt the few marginally successful mariculture enterprises now operating in the United States.

General Prognosis

It seems likely that "feedlot" production of marine fishes and invertebrates, on a commercially sound basis, will prove successful for at least some species. In my opinion, this will not happen quickly, and some new developments and breakthroughs, of both an engineering and a biological nature, may well be required before reliable and profitable mariculture of this kind will take hold. The danger is that repeated large-scale failures (the consistent pattern for the past decade) will discourage further investment of money and scientific effort in the field. It is to be hoped that such organizations as the National Sea Grant Program will continue to fill the gap between the laboratory experimenters and the large-scale entrepreneurs with support of some much-needed pilot-scale research, large enough in magnitude to reveal and address the problems of mariculture on a commercial scale.

But, aquaculture, freshwater or marine, that requires intensive artificial feeding and a high level of mechanization and/or labor cannot help alleviate the world food problem or even local shortages of animal protein. For such practices, like cattle feedlots, are food-consuming rather than food-producing systems; and the luxury crops they do produce, however successfully, are well beyond both the economic and the nutritional means of the people that most need a new, inexpensive source of protein.

Not so the extensive estuarine fish-pond farming of Southeast Asia, where mullet, milkfish, shrimp, and a few other species are grown on natural food. Requiring a minimum of labor and other operating costs and low capitalization, these practices can and do successfully produce significant quantities of high-quality and relatively low-priced animal protein. The same is true of bivalve mollusc culture, the only other form of mariculture that is an established and economically viable practice almost worldwide. Shellfish culture is more "intensive" than fish-pond culture, with respect to spatial requirements and the density of the cultured animals, because the molluscs concentrate the natural food produced over a much larger area and brought to them by water movement; but the principle is the same. No artificial external feeding is required, and the attendant problems and costs described above are avoided.

The major constraint to these forms of mariculture has been the limited supply and relatively high cost of juvenile animals obtained from the natural nursery areas. Instead of food and labor, it is the young animals that represent the single greatest cost to the fish farmer. Here is where modern technology could make an important contribution. It was noted above that mullet, shrimp, and many species of molluscs can now be artificially propagated in hatcheries. There appears to be no reason why milkfish would not eventually yield to such manipulation or, failing that, could not be replaced by other species that can be so reared. The point was also made that once the problems of artificial propagation are solved, the hatchery production of vast numbers of juveniles usually becomes routine and surprisingly inexpensive, and does not require large or expensive facilities. The establishment of hatcheries and the training of personnel to operate them could therefore provide a valuable stimulant to the expansion of what is already an established and successful form of mariculture.

The other constraints to the further development of estuarine pond culture in the developing countries are largely of a social-political-economic nature and involve providing access to coastal wetlands, low-interest loans, and other incentives to potential mariculturists. Perhaps educational programs, coupled with such technological advances as the hatcheries discussed above, would bring about a climate conducive to significant expansion of the industry.

What is the potential of coastal fish farming? How much can this already impressive industry be expanded? In the Philippines, where 380,000 acres of milkfish ponds were in operation in 1970, another 1,200,000 acres of undeveloped

A typical tambak, or brackish-water fish pond, in Indonesia. High yields of fish protein are achieved in these areas. (FAO)

mangrove swamps have been designated as available for such purposes. In Indonesia alone, according to FAO estimates, there are some 15 million acres of coastal wetlands that could be converted to fish ponds. At the present best annual yields of one metric ton per acre, fish farming in these designated areas alone could supply the protein requirement of these countries.

There are on the order of one billion acres of coastal wetlands in the world, mostly mangrove swamps in the tropics. These areas are ecologically and esthetically valuable, and no one would like to see a major portion of such resources sacrificed to food production. (It is interesting, however, that man is not nearly so reluctant to use all that remains of his natural terrestrial environment for agriculture and livestock grazing—an area already comprising 8 billion acres, or about 25 percent of the Earth's land surface.) Nevertheless, the use of only 10 percent of these wetlands, 100 million acres, could result in the production of 100 million metric tons of fish, using only the simple, unsophisticated techniques now commonly practiced in Southeast Asia.

The annual landings from commercial fishing for the entire world are only about 70 million metric tons today, and various estimates have placed the potential sustained annual yield at figures as low as 100 million tons. A substantial fraction of these landings represent "commercial" species used only for fish meal and only indirectly consumed by man. Because of that and the inevitable waste involved in processing, transporting, and marketing fish caught long distances from their ultimate utilization (i.e., about half of the weight of most edible fishes is, at best, the edible portion), only about 17 percent of the total tonnage of commercial fish landings is actually consumed directly by man.

Fish grown in estuarine farm ponds, on the other hand, may be cultivated over extensive coastal areas where they may be marketed locally, often consumed by the grower as a form of subsistence farming, and as much as 50 percent of the total production may end up as human food.

The above projections, it should be remembered, are based on the better present-day yields of fish farming in Southeast Asia. It should eventually be possible, by application of appropriate management techniques now being developed for modern aquaculture, to increase these yields as much as tenfold, still using the same basic methods of extensive aquaculture with no extraneous feeding. Controlled fertilization of ponds to increase their basic productivity and provide more natural food to the cultured species is an established practice, first developed for freshwater farm ponds in the Southeastern United States. The cost of fertilization can be greatly decreased by recycling domestic and agricultural wastes, making such improvements economically feasible. Genetic improvement of stocks, control of diseases and parasites, elimination of predators and competitors, population management of the cultivated species to maintain maximum carrying capacity in the ponds, improved pond design and harvesting methods; these and other promising new developments can significantly increase yields.

In short, combining the best features of modern intensive mariculture with the traditional, established fish farming practices of Southeast Asia could very well place aquaculture in a significant position in world food production. In that event, 100 million acres or more of coastal wetlands may represent a potential resource that can hardly be ignored.

The real potential of mariculture thus lies not in placing oysters, salmon, or shrimp on the plates of an affluent and already overfed society, but in providing substantial amounts of low-cost and high-quality animal protein to those people who have the nutritional need and the available land but who require only social and technological assistance to realize the food-producing potential of their coastal wetlands.

John H. Ryther is a senior scientist in the Department of Biology, Woods Hole Oceanographic Institution.

Source: Oceanus. "Food From the Sea." vol. 18:2. Winter 1975.

Study Questions: Mariculture: How Much Protein and For Whom?
Oceanus. Winter 1975 Food From the Sea
by John H. Ryther.

1. What are some of the prerequisites necessary for a successful mariculture industry?

2. Note the types of mariculture that exists in the world. Which areas of the world devote more time and effort to this mariculture?

3. Which forms of marine life have been most successful in the mariculture programs?

4. What are some of the major disadvantages or problems connected with mariculture?

5. What is the usual conversion efficiency rate in mariculture? Explain the percentage of input and resultant fish production.

6. What is the general outlook for the economically successful production of marine fishes and invertebrates?

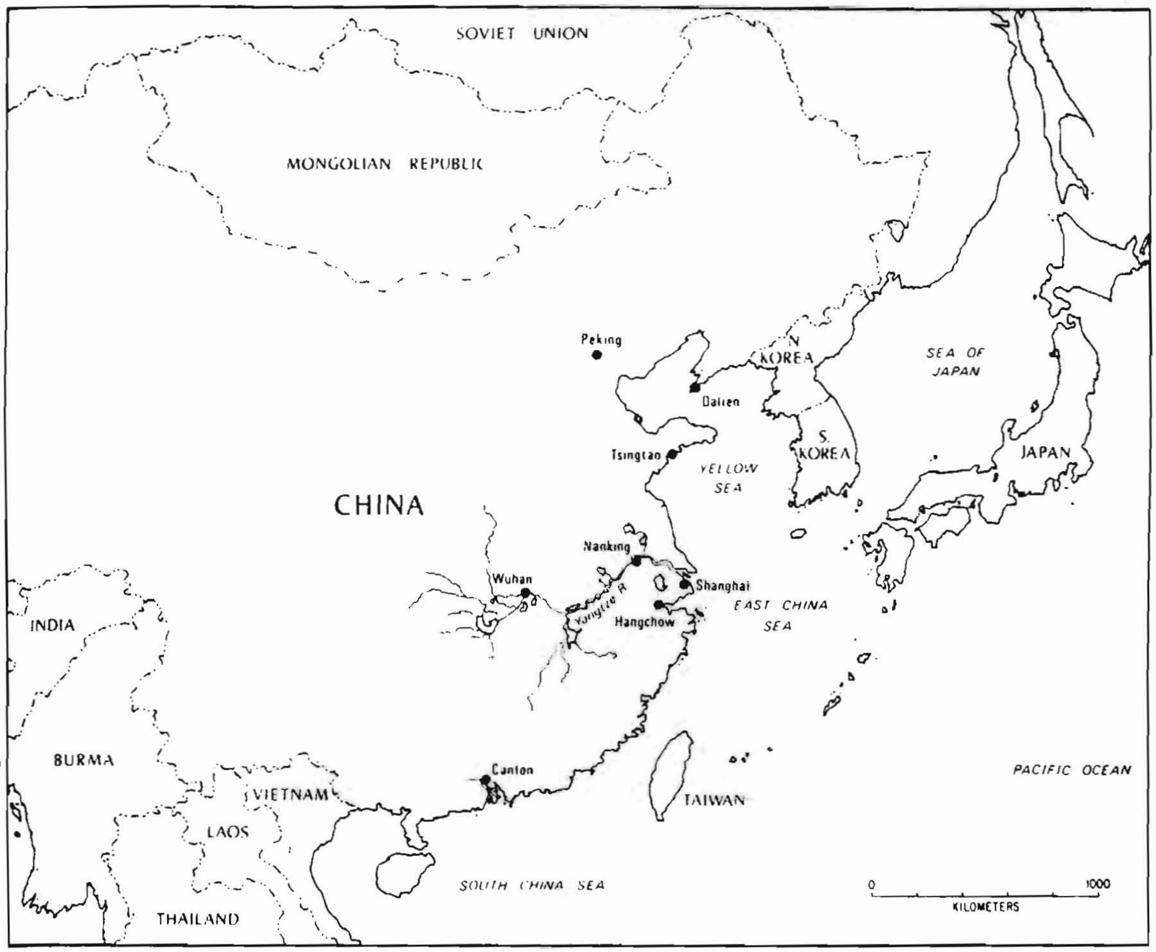
7. What is the relationship between mariculture and the developing nations of the world? Cite specific areas of the world where successful mariculture has taken place among the developing nations.

8. What projections have been made for coastal fish farming? Note specific areas.

9. What is the commercial fish landing statistic? What is this fish utilization? What percentage is actually consumed directly by man?

10. What are the final projections for mariculture throughout the world. Specifically comment on mariculture in the developing world. Include your own conclusions.

AQUACULTURE IN CHINA



by John H. Ryther

EDITOR'S NOTE: The author visited the People's Republic of China for a month in the fall of 1978 as part of a 10-member delegation of American oceanographers. He traveled to nine locations, including the country's largest oceanographic center at Tsingtao. The following article is based on his visits to both marine and freshwater aquaculture sites.

Freshwater fish production in China probably exceeds that of the rest of the world combined, perhaps by as much as several-fold. The total world production from all forms of aquaculture was recently placed at six million metric tons in a report by the National Academy of Sciences. That figure is unrealistic, however, since no reliable data were then available from the People's Republic of China. In fact, such data may not exist, but some reasonable estimates can now be made on the basis of information recently obtained.

Several independent studies have placed the total area of freshwater in China at about 20 million hectares (50 million acres). About half of that area is suitable for fish culture, and in keeping with the Chinese principle of multiple, intensive use of all natural resources, virtually all suitable waters are stocked with fish and managed to some degree.

About half of the 10 million hectares of managed freshwater consists of large, natural lakes or man-made reservoirs which, because of their size, receive less intensive management than small bodies of water — for example, no feeding, fertilization, disease, or predator control. Annual yields from these larger bodies of water vary widely, reportedly ranging from 50 to 5,000 kilograms per hectare. For example, the yield reported for Tung (East) Lake near Wuhan, which covers an area of 1,500 hectares and is managed by provincial culturists, is 450 kilograms per hectare annually, while that from West Lake near Hangchow, a 560-hectare body of water, is 1,300 kilograms per hectare.

The remaining 5 million hectares of managed freshwater are small, intensively farmed ponds. For the most part, these are managed by agricultural communes, by fish-farming communes, and communes that farm fish as an ancillary activity. In the agricultural communes, fish farming is closely integrated within the total food production system, whereas the fish-farming communities, in addition to fish production, also provide fingerling stocks for the agricultural communes.

The smaller, more intensively managed fish ponds are more productive, yields ranging widely from about 1,000 to 10,000 kilograms per hectare per year, and averaging perhaps 3,000 kilograms per hectare per year. In 1977, the Ching Po Fish Farm outside Shanghai produced 4,600 kilograms per hectare, expected to see a yield of 5,600 kilograms per hectare in 1978, and aspired to an annual yield of 7,500 kilograms per hectare — the reported performance of a nearby farm in Kanus Province.

Estimating yields of the less intensively managed larger lakes and reservoirs at a conservative 500 kilograms per hectare and that of the smaller fish farms at 3,000 puts total annual production of freshwater fish at about 17.5 million metric tons. Clearly this figure — nearly 25 percent of the total annual landings from all oceans — needs verification, but whatever the correct number, it would appear to be significantly greater than earlier estimates of China's freshwater fish production.

This yield also appears to be considerably larger than China's total marine fish landings, estimated at 3.1 million metric tons per year. The latter figure, hitherto unavailable to fishery statisticians, was derived from interviews with fishery biologists located at different points along the Chinese coastline. It is certainly not an insignificant figure — American fishermen only landed 2.3 million metric tons in 1977 — though the marine catch is almost dwarfed by the apparent contribution from aquaculture.

The combined yields from aquaculture and marine fishing — 20.6 million metric tons — is equivalent to a per capita fish consumption of about 45 pounds per year for the one billion or so inhabitants of China. This is not unreasonable for a country that so highly prizes fish as a food and whose other sources of animal protein are severely limited. It is significantly greater than the 17 pounds per year eaten by the average American, but we are not a fish-eating society. The Chinese figure is precisely the same as that of Sweden, and two-thirds that of Japan.

There are nine marine fishing corporations located along China's coastline. The second largest of these, located in Dalien, is an organization that builds, maintains, and operates 150 fishing and support vessels; owns its own freezer, ice plant, net manufacturing plant; and conducts its own processing, packing, sales, and distribution. Much of its annual catch of about 75,000 tons is frozen. Some of the more valuable species, such as shrimp, are exported to the United States and elsewhere. The bulk of the catch, however, is distributed throughout China.

The nine large fishing corporations combined only account for about a half million metric tons, or 16 percent of the total marine landings. The rest of the catch is landed by hundreds of thousands of fishermen in small boats at remote coastal villages that have little or no processing, refrigeration, freezing, or distributional facilities. The catch, therefore, must be consumed quickly and locally.

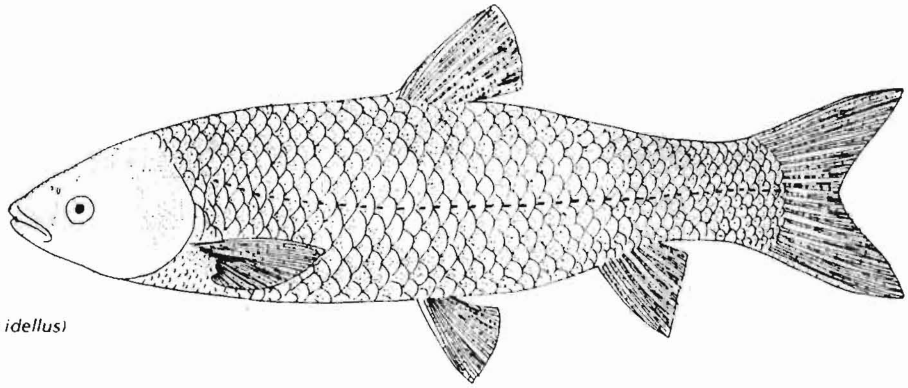
We can see then the importance of aquaculture in providing the large Chinese populace with an abundant supply of high-quality, extremely popular animal protein at reasonable cost. The distribution of farm ponds throughout the country, particularly in the south where water is abundant, makes it possible to market fresh fish without the problems of large-scale processing, freezing, and distribution.

In the size range of two to four pounds, fresh, pond-grown carp sell in the retail market for about the equivalent of 50 cents a pound. Smaller fish sell for about half that price. Chicken, duck, and pork, the other common forms of animal protein, are rationed because they are in short supply, and cost two to three times the price of fish.

How the System Works

Aquaculture in China owes its success to a number of factors. The multiple use of aquatic resources, referred to earlier, is probably the primary one. Reservoirs and smaller farm ponds may be constructed initially for irrigation or domestic water supply, but for the Chinese policy maker it is inconceivable that they not be simultaneously used, and to the limits of their capacity, for fish production.

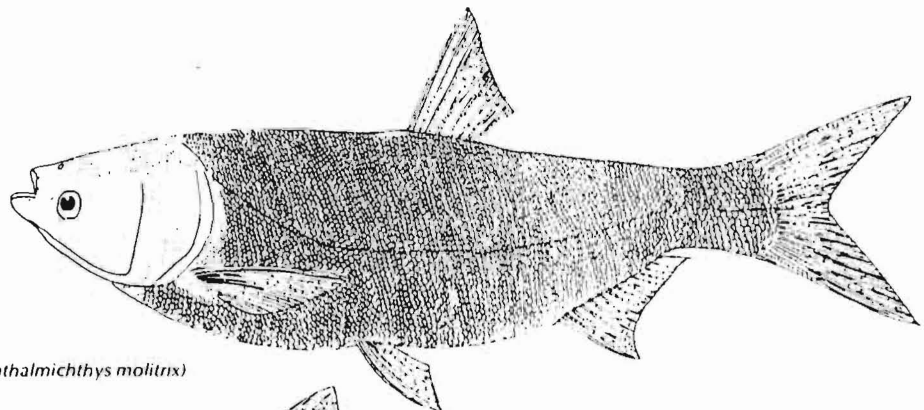
From its beginning, fish pond culture in China has always been considered an integral part of agriculture. The terrestrial and aquatic farms supplement each other in a number of important ways that increase yields of each component part. And mixed species cultivation or "polyculture" is



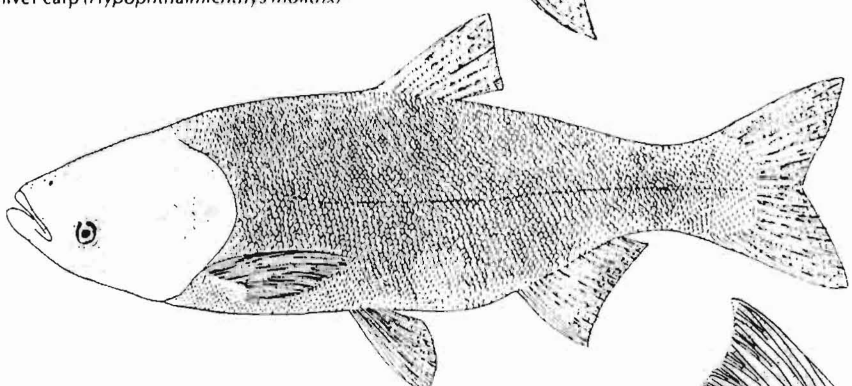
Grass carp *(Ctenopharyngodon idellus)*

universally applied, with particular emphasis on species low in the food chain.

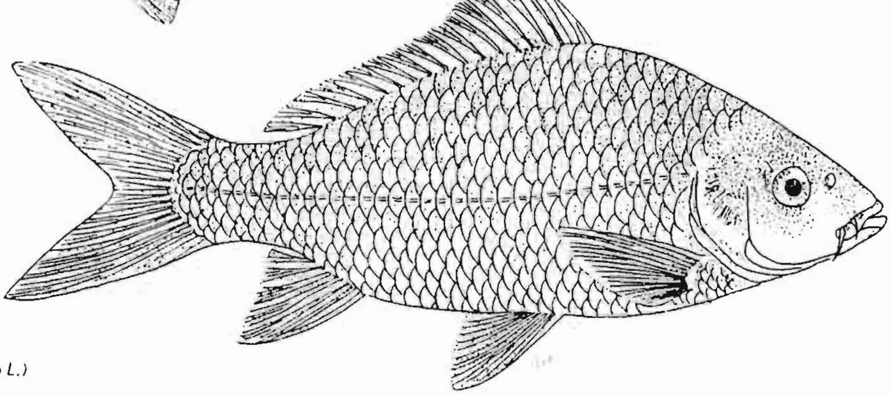
Virtually all of the fish species used in Chinese pond culture are cyprinids (minnows). The four most important and most universally used (the so-called major or Chinese carps or "family fishes") are the grass carp, *Ctenopharyngodon idellus,* the silver carp, *Hypophthalmichthys molitrix,* the bighead carp, *Aristichthys nobilis,* and the black or snail carp, *Mylopharyngodon piceus.* Also used are smaller numbers of mud carp, *Cirrhinus molitorella,* common and mirror carp *Cyprinus carpio,* golden and crucian carp, *Carassius auratus,* and the pond fish *Tilapia* (see page 29).



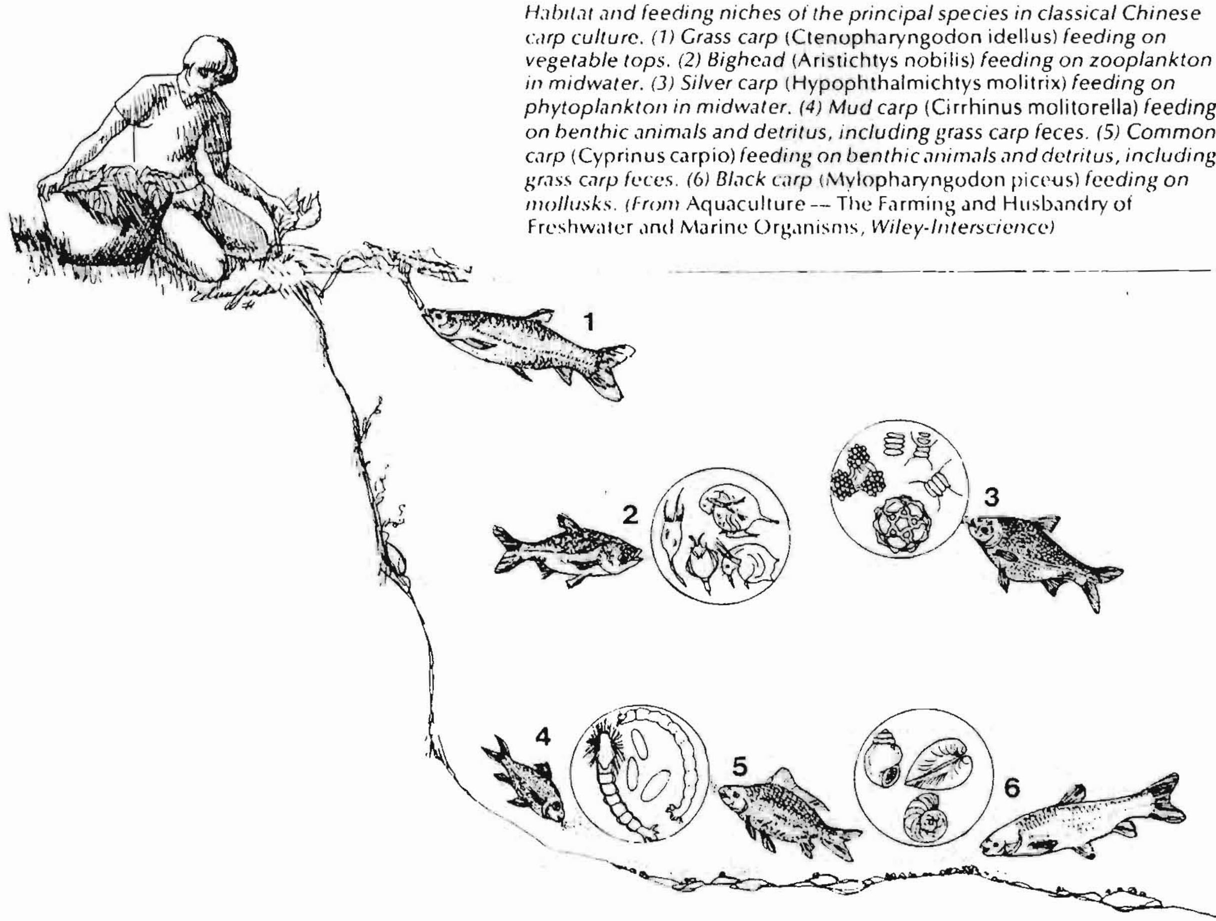
Silver carp *(Hypophthalmichthys molitrix)*



Bighead carp *(Aristichthys nobilis)*



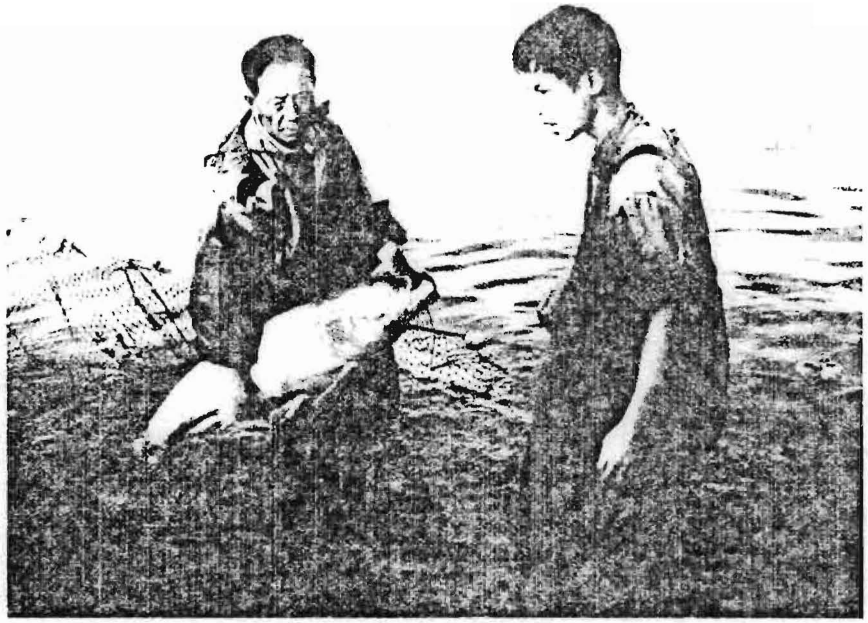
Common carp *(Cyprinus carpio L.)*



Habitat and feeding niches of the principal species in classical Chinese carp culture. (1) Grass carp (Ctenopharyngodon idellus) *feeding on vegetable tops. (2) Bighead* (Aristichtys nobilis) *feeding on zooplankton in midwater. (3) Silver carp* (Hypophthalmichtys molitrix) *feeding on phytoplankton in midwater. (4) Mud carp* (Cirrhinus molitorella) *feeding on benthic animals and detritus, including grass carp feces. (5) Common carp* (Cyprinus carpio) *feeding on benthic animals and detritus, including grass carp feces. (6) Black carp* (Mylopharyngodon piceus) *feeding on mollusks. (From* Aquaculture — The Farming and Husbandry of Freshwater and Marine Organisms, *Wiley-Interscience)*

The grass carp is a herbivore that normally eats aquatic macrophytes (both rooted and unattached and submerged and floating aquatic weed species); it also will feed voraciously on terrestrial plant wastes, such as cut grass and vegetable tops. Although fast growing (5 to 10 kilograms per year, or more), the grass carp is highly inefficient in its utilization of food, producing large quantities of organic wastes. This material settles to the bottom, supporting a community of benthic invertebrates that, in turn, serve as food for the black, common, mud, and golden carps. The wastes also decompose, liberating nutrients that support communities of phytoplankton and zooplankton, which in turn serve as the principal food for silver and bighead carps. The planktonic populations are further enhanced by periodic fertilization of the ponds with fermented pig manure or other organic wastes, such as that from ducks (often raised in the same ponds with the fish). It is the combination of polyculture, which takes advantage of every feeding niche in the pond ecosystem, and utilization of agricultural wastes that results in the low-cost, high-yield achievements of Chinese pond culture.

The major carps normally live in large river systems, and they are unable to spawn naturally in the stagnant farm ponds. Up to 1958, the industry depended on the annual collection of fingerlings from their natural environment, but then an artificial spawning method was developed that involved injecting the fish with common carp pituitary extract or with human chorionic gonadotropin. Today most provinces in fish-farming regions of China have a commune that specializes in hatchery production and rearing of fry for distribution to other communes. The personnel in these specialized communes are accomplished in such fields as controlled induced spawning, selective breeding, larval rearing, disease prevention and treatment, and nutrition — areas normally requiring considerable training and experience in the Western world. At the Ching Po Fish Farm, workers claimed that they usually could diagnose, treat, and cure a disease problem in three days. They added that normal survival rates for fingerlings to marketable adults ranged from 90 to 95 percent. Members of all the fish farming communes take great pride in their ability to solve their own problems — even to conduct their own research as needed, independent of the academic or government research communities. The kinds of research that such production units can accomplish, however, are necessarily empirical, focused on immediate problems.



A bighead carp breeder seined from a fish pond at a fish-farming commune near Shanghai.

Institutional Research Programs

More basic research on freshwater fish culture problems is conducted on the provincial and national levels at a number of universities and institutes. At the Institute of Hydrobiology at Wuhan, for example, both basic and applied research is done on fish breeding and genetics, disease control, and the primary productivity of lakes and reservoirs.

The grass carp, the essential first-stage herbivore in the Chinese polyculture system, is difficult to rear in the early stages of its life cycle, being subject to severe disease problems. Scientists at the Wuhan Institute have successfully brought into culture another herbivore, the Chinese bream, *Megalobrama amblycephala*, which is hardier, perhaps superior as a table fish, and fills the same ecological niche as the grass carp. That fish has now been successfully introduced into 20 of China's provinces.

The same laboratory also has successfully crossbred several closely related cyprinids (for example, different varieties of the common carps) producing hybrids that are fertile, breed true, and grow faster and larger than either parent stock. These also are now available for distribution throughout China.

The ecological unit at the Institute of Hydrobiology studies the productivity of the larger lakes and reservoirs in China, including the 1,500-hectare basin of Wuhan's East Lake, which they selected as a model study area. The objective of this group is to determine the maximum carrying capacity of the lakes and reservoirs so that they can be stocked to that level, thereby achieving maximum potential yield without stunting or stressing the fishes. Other objectives are to determine the proper stocking ratios of different species so as to maximally utilize all feeding niches, and to stock the proper number of grazing and filter-feeding herbivores so as to preserve a desirable level of aquatic macrophytes and phytoplankton for aesthetic purposes, since the lakes also are used heavily for recreation. To achieve these objectives, the staff studies chemical nutrient cycling, primary productivity, and the distribution of phytoplankton and zooplankton, with the ultimate hope of developing a numerical model for predicting potential fish yields.

During the early 1970s, an ovulating agent for induction of spawning by farm fishes was successfully synthesized, tested, and evaluated through a cooperative research project involving the Shanghai Institute of Biochemistry, the Peking Institute of Zoology, and other organizations. The agent (an analog of the nonapeptide LH-RH) is now commercially available, though the extent to which it has replaced the use of carp pituitary (still used exclusively in the United States, and elsewhere) is not known.

Marine Aquaculture

Marine aquaculture is a more recent innovation in China, dating from post-revolutionary times. Many marine species are being grown experimentally along the entire Chinese coastline. These include the seaweeds *Laminaria japonica* (kelp), *Undaria pinnatafida*, *Porphyra yezoensis*, *P. quangdongnesis*, *P. haetanensis*, *Gracilaria* *verrucosa*, *Eucheuma gelatinae*, and *Ligera* sp.; the mussels *Mytilus edulis*, *M. virides*, and *M. smarajdinus;* the oysters *Ostrea rivularis*, *O. plicatula*, and *Crassostrea gigas;* the clam *Arca granosa;* the scallop *Chlamys farreri;* the sea cucumber *Stichopus japonicus;* the penaeid shrimp *Penaeus orientalis*, *P. merguiensis*, and *P. monodon;* the pearl oyster *Pinctada martensci;* the crab *Erochier sinensis;* and certain finfishes, including mullet, *Mugil so-iuy*, and milkfish, *Chanos chanos*. Several of these species are already in some form of commercial production, but data are not generally available.

The most important cultivated marine organism is the brown seaweed, *Laminaria japonica*, a cold-water species of kelp originally introduced to China from Hokkaido, Japan. Formerly imported from Japan, *Laminaria* is now grown in more than 3,000 hectares of China's northern coastal waters with a production of some 10,000 dry tons per year, roughly half of which is consumed directly as food and half of which is used for the extraction of alginates. More than 1,000 dry tons per year are now exported to Japan, where production is declining.

Kelp culture is started in one of 15 hatcheries in northern China. Such hatcheries are essentially large greenhouses covering shallow tanks through which fertilized, refrigerated (5 to 8 degrees Celsius) seawater is circulated. Kelp spores attach in the spring to 50-meter-long strings wound on wooden frames that are submerged in the hatchery tanks, the spores developing to 2 to 4 centimeter sporelings during the summer and early fall. When the coastal seawater temperature drops below 20 degrees Celsius, the strings, with the sporelings attached, are removed from the wooden frames, moved outside, and attached to buoyed ropes. During the following six to eight months, the plants are manually thinned, transferred to larger ropes, carefully brushed individually to remove sediments and epiphytes, and fertilized daily. They thus grow to mature sporophytes, ranging in length from 3 meters in the Tsingtao area to more than 5 meters in Dalien, where the water cools more quickly in the fall and the growing season is longer. Annual kelp production in the two areas is roughly 30 and 50 dry tons per hectare, respectively. The wholesale value of dry kelp in China is equivalent to 60 cents a pound.

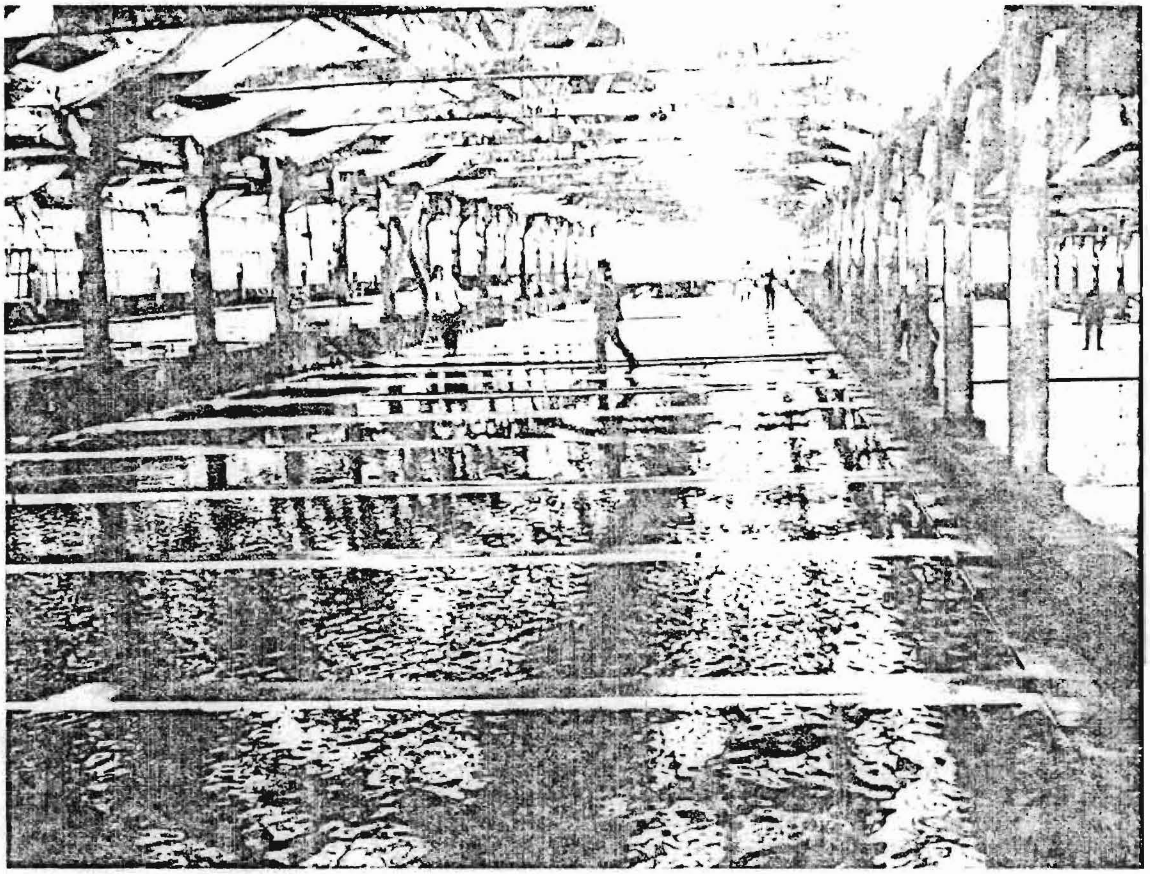
The cultivation of the red seaweed, *Porphyra*, is a more recent introduction, still undergoing development. Essentially the same technology is used for growing this alga in China as is employed in Japan. Since the latter has been thoroughly documented elsewhere, the practice will not be described here except where there is a significant difference. A recent Chinese innovation is to spread the nets (to which the spores and later the mature plants are attached) under floating bamboo rafts, in contrast to the fixed nets attached to poles driven into the bottom, which are used in Japan. The floating rafts keep the plants permanently at or just below the surface and this has reportedly enhanced yields greatly. Another departure from Japanese *nori* culture is the fertilization of the *Porphyra* beds, accomplished by attaching small plastic bags of fertilizer to each bamboo raft through which the nutrients slowly diffuse as they dissolve.

The small, cold-water species of *Porphyra* (*P. yezoensis*), which was also introduced from Japan, is grown in northern China, where a yield of about 0.6 dry tons per hectare per year is obtained. In the South China Sea region, the more tropical *P. haitanensis* is grown, reportedly reaching a length of more than 9 meters in contrast to *P. yezoensis*, which grows to about 1 meter in the north. Yields of *P. haitanensis* from large production units are on the order of 8.5 dry tons per hectare per year and those from small, experimental units are reported to be as high as 20 tons per hectare per year. Yields of *Porphyra* in China, though significantly higher than those in Japan, are much less than those of *Laminaria*, but the higher price of *Porphyra*, more than five dollars per pound dry, makes its cultivation popular.

The City of Tsingtao is China's main center for marine research, harboring the Institute of Oceanography (Chinese Academy of Sciences), Shantung College of Oceanography, and the Yellow Sea Fisheries Institute (National Bureau of Fisheries). The Deputy Director of the Institute of Oceanography, C. K. Tseng, is a phycologist who received his doctorate from the University of Michigan, later working at Scripps Institution of Oceanography in California before returning to China. T. C. Fang, Chairman of the Biology Department at Shantung College, is a noted algal specialist. Understandably, then, there is emphasis within the Tsingtao scientific community on seaweed research.

Scientists at the Institute of Oceanography have had considerable success (through X-ray-induced mutation and selective breeding) in developing pure strains of *Laminaria* that grow more rapidly than wild populations, contain more iodine, and can tolerate high temperatures. The latter feature is an important attribute that allows extension of the species' southern range and a corresponding expansion of the *Laminaria* culture industry.

Fang is carrying out interesting and highly original basic genetic studies on *Laminaria*. By treatment with colchicine at low temperatures, he has been able to induce the microscopic female gametophyte of *Laminaria* to develop parthenogenetically into a large, undifferentiated cell mass (callus). Each callus may be considered as a genetically pure clone that can be maintained indefinitely — each cell of which, when isolated and


One of the large greenhouses used as kelp nurseries in Tsingtao.

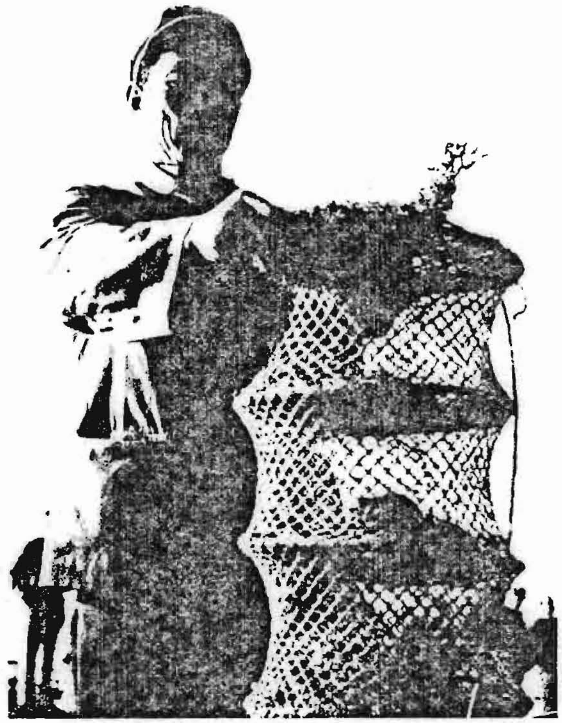
returned to its normal environment, will develop into a normal female sporophyte (or commercially valuable seaweed plant). This pioneer work in seaweed genetics opens the door to the development of pure-breeding, improved stocks of this important seaweed, following in the footsteps of modern higher plant genetics.

Mussels, Scallops, and Shrimp

In both the Tsingtao and Dalien regions, the same fishing communes that culture seaweeds also culture several kinds of invertebrates. Mussels, *Mytilus edulis,* are grown on buoyed ropes, using essentially the same techniques as those developed in Spain and now widely adopted in many other countries, including the United States. About 18 months is required for the mussels to reach marketable size: there are two crops a year, spring and fall, producing about 480 tons (shells included) per hectare (compared to some 600 tons per hectare per year in Spain for the same species).

Smaller numbers of scallops, *Chalamys farreri,* are grown in the same areas, the juveniles suspended from ropes in layered "lantern baskets." Sea cucumbers, *Stichopus japonicus,* also are released on the bottom as juveniles beneath the *Laminaria* and/or *Mytilus* cultures, where they live on sinking detrital material produced by the plants and animals above. The non-motile animals are harvested by divers two years later when they reach a marketable size of 8 to 10 centimeters. The mussels, scallops, sea cucumbers, and several other species of invertebrates (abalone, clams, oysters) are relatively recent introductions, still largely in the experimental stage. The production units themselves do most of the empirical experimentation, including spawning and larval rearing in their own hatcheries. For example, at the Chin Hsien County Aquaculture Station near Dalien, seed scallop production has increased from 1.7 million in 1977 to 7.9 million in 1978 through the use of improved spawning and larval rearing techniques.

Several of the same species of penaeid shrimp that are grown successfully in many parts of Southeast Asia are also cultivated in the South China Sea coastal area, using essentially the same methods and gaining the same results. But in the East China Sea and Yellow Sea coastal regions, the large "Chinese" shrimp *Penaeus orientalis* is also grown with considerable success. According to Liu Jiu-yu, crustacean specialist and Head of the Zoology Department at the Institute of Oceanography, *P. orientalis* routinely matures sexually in captivity in holding ponds, in contrast to other penaeid shrimp species cultured elsewhere, where gravid females must usually be taken from the commercial fishery to obtain the young. Larval



Multi-layered "lantern" nets used for scallop culture.

stages are hatchery reared as is done elsewhere and post-larvae are grown to more than 15 centimeters (25 grams) in length in less than five months, making it possible to grow the animals to a large marketable size in one brief season.

This relatively temperate-water, easily grown shrimp species would appear to be of potential interest to culturists elsewhere in the world, including the United States. It could be one of the first Chinese contributions to aquaculture in the United States in what one hopes will be a new era of marine scientific exchange between the two countries.

An Example to Learn From

China has long been recognized as both the pioneer and the most successful practitioner of fish farming in the world. What has not been fully appreciated is the magnitude of that success or the broad diversity of new efforts in Chinese aquaculture, particularly in the oceans.

With the field of aquaculture still struggling to fulfill its promise almost everywhere else in the world, it is gratifying to see the Chinese example, and challenging to contemplate how we may benefit from that experience.

John H. Ryther is a Senior Scientist in the Biology Department at the Woods Hole Oceanographic Institution.

The carp drawings accompanying this article were done by Dr. Shao-Wen Ling, appearing in his book *Aquaculture in Southeast Asia*, a University of Washington Sea Grant publication, 1977.

 Source: Oceanus. "Food From the Sea" vol. 18:2. Winter 1975.

SPECIFIC NEW ENGLAND CONSIDERATIONS

There are a variety of maritime related problems which directly impact the New England area. Only two specific problems are in included in this Learning Activities Packet, Facility Siting and Oil or Fish on the Georges Banks. The student will observe that all previous materials contained in this LAP does apply to New England.

Specific New England Problems and Concerns

Facility Sitings

Power plants are often sited in the coastal zone for a variety of reasons. In some instances a relatively remote area is chosen. It is often a marshland area that formerely was not considered valuable shore land for other types of buildings or uses. It is known today that the marshland isthe prolific food factory that provides the nutrients for the complete ecosystem of our coastal and ocean waters from the photoplankton/zooplankton throughout the complete food chain to the largest of marine mammals, the whales. These nutrients that are produced in the estuarine and marshland areas are washed out to sea daily with the tides and supply the myriads of living organisms in the sea with sustenance. The importance of and the necessity for these marshlands is realized today. Laws have been established to protect this viable land area particularly the Coastal Zone Management Act of 1976. In some instances "artificial" marshlands have been constructed following the discovery of their valuable function and the post realization of the impacts resultant from their destruction.

The "remote" location area for the power plant may have been chosen for the siting due to its distance from populous areas. Many people do not consider power plants as attractive components of their residential neighborhoods.

Coastal areas were also sought for power plants because of the availability of cooling waters which is a necessary component in the generation of power. This operational aspect of the power plant may cause far reaching impacts on the existing ecosystems. This can include the destruction of the organisms that are living within the waters that are actually circulated through the power plant. Most power plants have some type of screening device which will eliminate larger organisms from entering the circulatory systems and certain destruction. Smaller organisms and microorganisms are usually doomed for destruction. Another impact of the cooling system is the discharge of the water into the coastal waters. This discharged water will often range from about 10' to 34' F hotter that when it entered the plant. The effects of this warmer discharge water may effect the surrounding ecosystems in a 35 mile area. There may be additional environmental impacts if dredging must be done for the intake and discharge functions of the facility to operate.

Studies have shown that as much as 30%, if not more, of the animal brood of estuarine spawning fish can be killed by the operation of a 1,000 megawatt plant located on a semi-enclosed ecosystem or breeding area.such as the Indian Point Plant on the Hudson River.

Urban areas also have been chosen for facility siting. Some of the reasons for such choices are obvious. These include the demands of the surrounding urban areas, the needs of the local industrial plants, and the convenience of the adjacent port facility through which the oil (or coal) is transported for the generation of power at the facility. Note that usually the majority of the power facilities in the urban areas are of an older type and as such contain fewer protective devices for a harmonious interaction with the ecosystems surrounding it. In some instances laws, Federal, State, and local, have been passed which mandate certain regulations regarding these facilities. In some instances these regulations may apply only to newer plants, and the older ones may be exempted.

The average American has a great dependence on multiple utilities that are powered by facility plants. The usage includes direct usage such as electricity, telephones, television, plumbing facilities, numerous small appliances,etc. as well as an indirect dependence on the myriads of products that are such an essential part of our daily life and are manufactured through a process that directly involves the power generated from the power plant.

The siting of power and water treatment plants involves difficult decisions particularly if it concerns the coastal zone. As we continue to study and learn more about the interactions of the fragile ecosystems of the coastal zone, the conflicting uses and needs of this area become more apparent. This knowledge may also make the decision more difficult. Citizens must be informed about these basic issues and the impact that their decisions will have on the marine environment.

Specific New England Problems and Concerns

Student Activities

1. Research the number, types, and capacity of the power plant facilities in the Commonwealth of Massachusetts.

2. Complete the following data relative to these facilities:
   a. Type / location / capacity of each plant
   b. The original date of operation. (Also include any major expansion of this facility.)
   c. Determine whether this plant is involved in the New England "power pool".
   d. Briefly explain how the New England Power Pool operates.
   e. Include, if available, the projected usage and capacity in the Commonwealth of Massachusetts.

3. Review and list the major steps that have to be followed for the siting of a power plant in the State of Massachusetts
   a. Specify those laws and regulations that are Federal and those that are State laws. In some instances there may be local ordinances that also regulate facility siting.
   b. Determine whether these regulations affect only new plants, or whether they also apply to older plants.

4. Determine what the impact from this facility on the ecology of the environment and the recreational uses of the immediate area.

Extra Credit

1. Complete this same research for the entire New England area.

2. Research the background, current status, and projections for the nuclear power plant in Seabrook, New Hampshire.
   a. Give the background for the numerous demonstrations and delays in the building of this facility. Present both views to this controversial facility.

Student Activities

b. Determine why this facility was placed in Seabrook, New Hampshire.

c. Make an analysis of Federal/State/Local regulations relative to this siting.

d. What capacity will this new facility add to the State of New Hampshire, the New England region, the New England power pool, and areas beyond New England.

e. Determine whether there are other nuclear facilities in New England. List the number/location/capacity of each plant. Determine the contribution that these plants have for the New England region.

f. Note the ecological impacts on the environment and the effect on the recreational uses of the immediate area. The information for this research can be obtained in the public libraries and from the Public Utility Departments of the respective States.

'So let them eat steak!'

The Boston Globe Wednesday, October 10, 1979

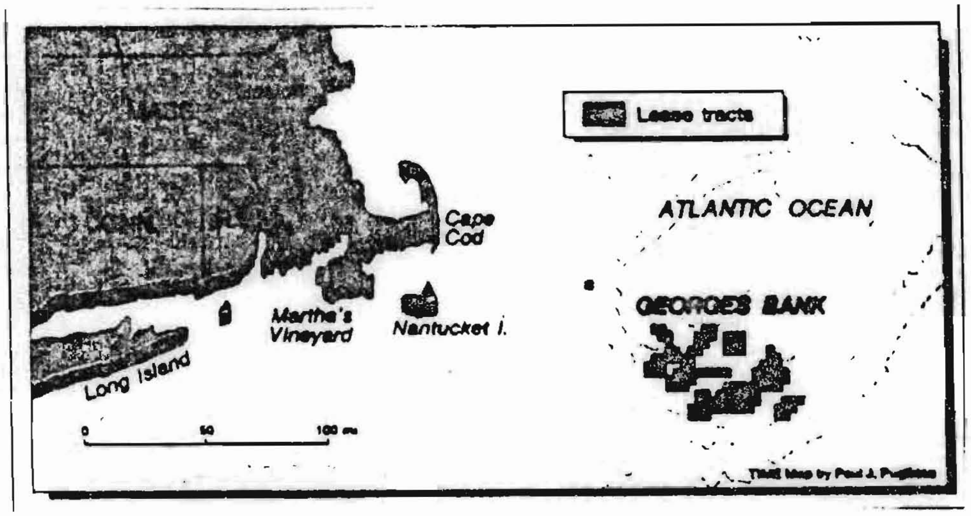
Nubar Alexanian—Picture Group

Protesters' bumper sticker: 'If we kill our spawn, where will we get our food?'

FISH OR FUEL

FROM THE

GEORGES BANK??



TIME, NOVEMBER 26, 1979

Georges Bank is located within 100 miles off the tip of Cape Cod, Massachusetts. It is located near the edge of the gradually sloping continental shelf, nearly 200 miles out into the Atlantic Ocean. This area is often referred to as the <u>Outer Continental Shelf</u> (OCS). It is precisely this unique <u>slope</u> of the continental shelf and the temperature of the North Atlantic waters -- warmed by the Gulf Stream-- that form the environment which produces an abundance of foods for the great variety of fish that habitually spawn on the edge of this shelf. Many favorable conditions make the Georges Bank among the world's most productive fishing grounds.

The Georges Bank provides about a $168 million (some sources will go as high as $1 billion) for the fishing industry annually. This is about 17% of the total American catch and 14% of the world's catch. Scientists have designated this area as the richest fishing area of the world. The Georges Bank also adds to the $1 billion tourist trade.

Georges Bank

Men have been fishing these waters for centuries. It is known that the French, Spanish, and Portuguese fishing fleets regularly fished the Banks during the 16-17th centuries. The fish would then be dried and salted on the beaches of North America and then packed into the holds of the ships and brought back to Europe for sale. This valuable and life sustaining resource has been renewing itself and providing food for man for over 300 years.

Today, the most common fish on the Banks are "ground fish" including: cod (chosen as the symbol of the Commonwealth of Massachusetts), halibut, haddock, hake, flounder, and many "underutilized" species such as: squid, eel, herring, etc. that are considered delicies in Europe but not favored by most Americans.

The value of this renewable resource has been so significant to New Englanders, who market this fish for the rest of the USA and for world wide consumption, that the US Congress passed a law to protect the Georges Bank from being "overfished". Effective in 1977, the US Government would not allow any foreign fishing boat within 200 miles of the USA coastline without a special permit. This "200 mile limit" law is known as FCMA (Fish Conservation Management Act). After the great and modern fleets of the USSR began to fish the Banks in the mid sixties, some species, especially halibut, nearly disappeared. Scientists state it will take years to bring the halibut back up to normal levels of production. It was seriously threatened by extinction.

Georges Bank

Many people today are concerned by what they feel is a new threat to the natural habitat of the Georges Bank. "Schools" of oil companies are drilling "exploratory" holes in and around the Georges Bank area in search of oil and natural gas. Studies prove that all the ingredients for oil and natural gas fields do exist in this area. (See illustration).p. 7.)

All the major oil producing companies (17 large ones and some independent ones) conduct their own expensive explorations. Each company carefully guards its "secrets". Knowledge is not shared among the companies nor with the Federal Government that also conducts surveys. The oil companies do not want to create more competition for themselves prior to the sale of the leases. Reseach techniques are constantly being refined and may give valuable information.

In the production of oil, there are three basic phases: exploration, development, and production. Each of these phases is very costly. The exploration phase on the Georges Bank was $828 million by the combined oil companies. An example of the cost during the exploration stage by the US Government included a "comprehensive arial survey by the USGS of the rock structure beneath the Atlantic continental shelf. Done in 1975, it would cost about $37 million to repeat in 1980. In 1976 during another phase of the exploration, the research included the drilling of two deep holes in the Georges Bank to study rock formation. This drilling alone cost nearly $40 million. Obviously these costly procedures have to be paid by the consumers.

The consumers of New England are in a bind. There is a large concentration of peoples in New England who depend on imported (foreign) oil. There is a high consumption rate of oil in New England. The typically cold and snowy winters demand a great consumption of oil. There are diversified industries located throughout this region that use this imported oil. New England is almost totally dependent on automobile and trucking for major transportation, and nearly all supplies and services. Railroad service has suffered a long decay and it gives only limited service throughout New England. Even the New England fishermen need the oil and gas to get out to the Banks area to fish. The need for a new oil supply is real and imminent for New Englanders as it is for all Americans.

The current explorations of the Georges Bank area (Spring 1980) has not proven very successful. It is estimated that at the very best there would be about 123 million barrels of oil. Should this be brought up in one single haul, it would be equal to the amount necessary to supply the U.S. with one week's supply. There are estimated to be slightly larger amounts of natural gas, but not of sufficient amounts to make this a meaningful discovery.

The problem becomes more complex when we realize that the New England fisheries industry is a most productive one. This includes not only the fishing boats, but many processing plants as well which furnish many jobs throughout the New England coastal states.

It is because of this fish industry that a private, non-profit citizens group - the <u>Conservation Law Foundation</u> sued the US Department of the Interior in an attempt to delay or stop the sale of leases in the Georgew Bank area. The first sale was announced on December 31, 1977. After a series of court proceedings at the state, federal district court, and the US Circuit Court of Appeals, the US Supreme Court issued an injunction (a court order to delay the sale) on February 1979. Proceedings continued with a tentative lease sale announced, various hearings conducted, and the case was finally sent back to the US Court of Appeals. It was finally determined that the lease sale would be possible on December 18, 1979 at 3:00 p.m. on lease sale # 42.

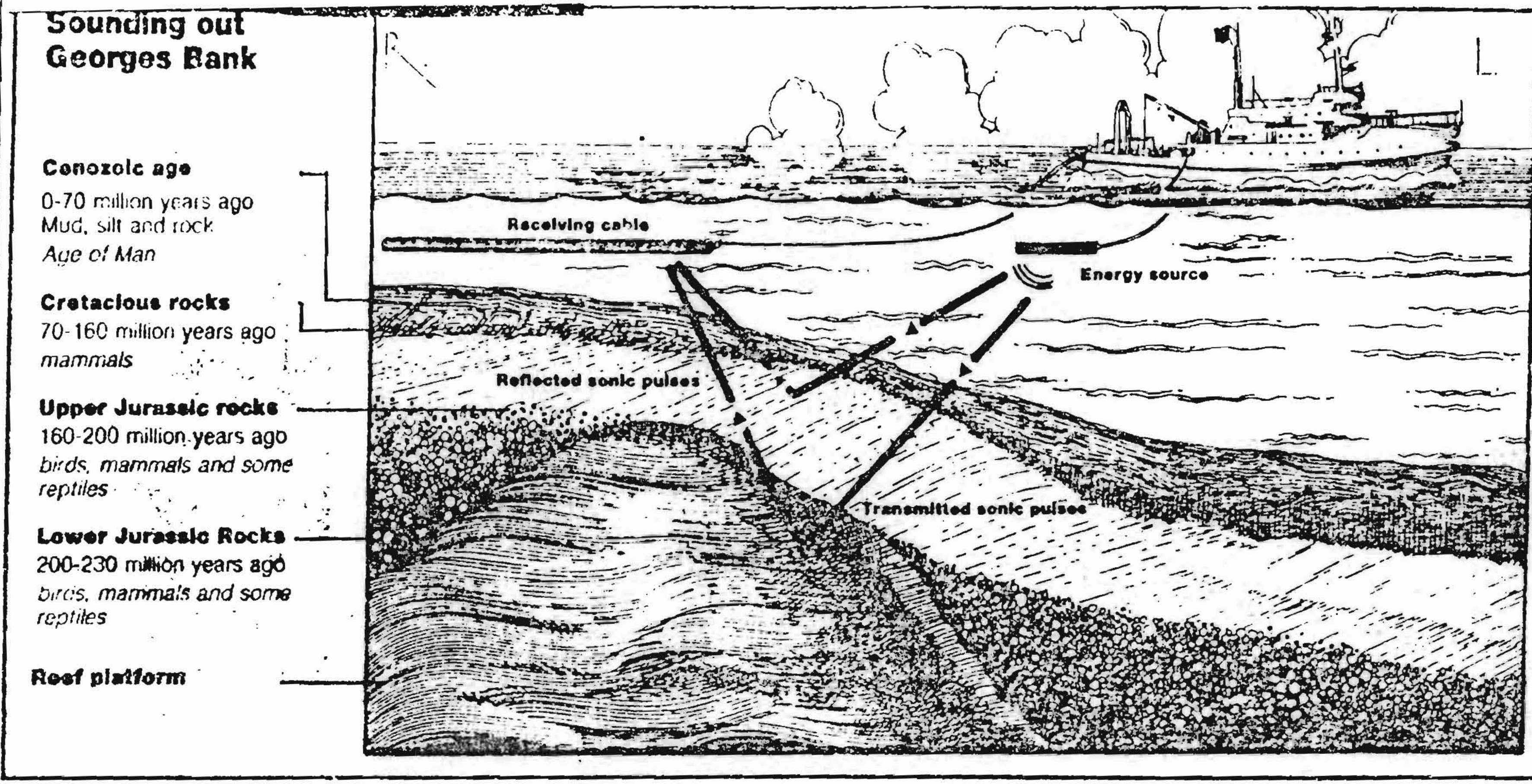
The lease sale is only the beginning of the process for the oil companies. A great number of special permits are required, a most detailed Environmental Impact Statement (EIS) must be completed which clearly shows the major impact on the fisheries based on known information and the problems that may arise during the three stages of oil production.

In the Georges Bank situation, a number of leases have been deleated from the sale -- due to the Banks being major spawning grounds for various species, having cracks in the ocean floor, and various seasonal problems.

There are a number of federal laws that govern the Georges Bank development. The OCS Lands Act specifically governs what the Secretary of the Interior may do. The National Environmental Protection Act insists on the Environmental Impact Statements which must include an analysis of the impacts, the costs, and benefits. The Endangered Species Act would prohibit the sale of leases if any endangered species were jeopardized. The Marine Sanctuaries Law identifies and manages specific areas of the ocean. The Fisheries Conservation Management Act (FCMA) -- the "200 mile limit Act" -- establishes a national goal or rebuilding, restoring, and maintaining fisheries. Finally there is the Administrative Procedure Act which states that any capricious act (abrupt act, usually on a whim) is illegal.

All these laws safeguard the Georges Bank area. They also delay the exploration of oil. The oil companies state it will be next spring (1981) at the earliest before they can complete all the requirements that are now demanded for the exploratory and development phases. The oil companies have further announced that it will be a minimum of 11 years before all the regualtions and approvals have been met for the actual production of oil in the Georges Bank area. This in turn means more monies for foreign oil which could become a political tool in the hands of the OPEC countries.

Sounding out Georges Bank



The Georges Bank odds

- A source — ancient organic material, from plants or dinosaurs or, more likely, other prehistoric animals, which could turn into oil or gas during eons of decay.
- A reservoir — porous rocks that would store the oil or gas for modern-day discovery.
- A trap — nonporous rocks lying above the reservoir rocks to prevent the lighter-than-water oil or gas from floating up and disappearing into the ocean or air.
- Heat — coming from the earth's core up through the crust, to mature or "cook" the organic matter into oil or gas.
- Depth — the organic matter also must be under enough pressure from the weight of rock above to allow that heat to do its work in a subterranean pressure-cooker.
- Timing — the trap rocks have to be in place before the oil or gas oozes into the reservoir rocks. Otherwise the oil or gas, which floats on the water that is also found in reservoir rocks, will have oozed away.

Georges Bank

Activities

The varied questions that are raised by a study of the Georges Bank Oil drilling problem lend themselves to a number of role playing activities. The following may assist you in planning the appropriate technique for your class.

1. A formal debate : Resolved: That Oil Drilling must take place on the Georges Bank As soon as possible to Alieviate the energy needs of the USA.

2. Role Playing: Public Hearings conducted by the EPA on:

   The Desireability of Drilling for oil on the Georges Bank.

   Participants must clearly develop a position statement based on the role chosen:

   EPA Officer - Presiding officer at hearings

   Drill-More Oil Co. Representatives

   Catch All Fisheries Groups

   Lobby Groups: Pro-oil - job seeking group

   Pro-fish - anti-oil group

   Scientists: Marine Biologists

   Geologists

   Oceanographers

   Mayor of nearby coastal town - favors jobs for high unemployed in town

   Resort/ Tourist interests -- anti oil

   Citizens Group that favors jobs promised by Oil companies

ABBREVIATIONS

ACC	Administrative Committee on Coordination (See U.N.)
ACDA	Arms Control and Disarmament Agency (See U.S. Government, State Dept.)
AFSIS	Aquatic Sciences and Fisheries Information System (See U.N., IOC)
AID	Agency for International Development (See U.S. Government, State Department)
ASEAN	Association of Southeast Asian Nations
ASW	anti-submarine warfare
av	audio-visual
BLM	Bureau of Land Management (See U.S. Government, Dept. of the Interior)
CARPAS	Regional Fisheries Advisory Commission for the Southwest Atlantic (See U.N., FAO)
CECAF	Fishery Committee for the Eastern Central Atlantic (See U.N., FAO)
CEQ	Council for Environmental Quality (See U.S. Government)
CIA	Central Intelligence Agency (See U.S. Government)
CIEP	Council on International Economic Policy (See U.S. Government)
CMEA	Council for Mutual Economic Assistance (Eastern European Countries)
COFI	Committee on Fisheries (See U.N., FAO)
CZM	Coastal Zone Management
DDT	
DIBA	Domestic and International Business Administration (See U.S. Government, Commerce Dept.)
DMA	Defense Mapping Agency (See U.S. Government, Defense Dept.)
DOMES	Deep Ocean Mining Environmental Study (See U.S. Government, Commerce Dept.)
DWT	deadweight ton
ECA	Economic Commission for Africa (See U.N.)
ECE	Economic Commission for Europe (See U.N.)
ECLA	Economic Commission for Latin America (See U.N.)
ECWA	Economic Commission for Western Asia (See U.N.)
EDS	Environmental Data Service (See U.S. Government, Commerce Dept.)
EEC	European Economic Community
EEZ	exclusive economic zone
EIS	environmental impact statement
EPA	Environmental Protection Agency (See U.S. Government)
ERDA	Energy Research and Development Administration (See U.S. Government)
ERL	Environmental Research Laboratories (See U.S. Government, Commerce Dept.)
ESCAP	Economic and Social Commission for Asia and the Pacific (See U.N.)
FAO	Food and Agriculture Organization (See U.N.)
FDA	Food and Drug Administration (See U.S. Governemnt, Dept. of Health, Education, and Welfare)
FEA	Federal Energy Administration (See U.S. Government)

GARP Global Atmospheric Research Programme (See U.N., WMO)
GEMS Global Environmental Monitoring System (See U.N., UNEP)
GESAMP Joint Group of Experts on the Scientific Aspects of Marine Pollution (See U.N.)
GFCM General Fisheries Council for the Mediterranean (See U.N., FAO)
GIFA Governing International Fisheries Agreement
GIPME Global Investigation of Pollution in the Marine Environment (See U.N., IOC)

HEW Health, Education and Welfare, Dept. of (See U.S. Government)

IAEA International Atomic Energy Agency (See U.N.)
IBRD International Bank for Reconstruction and Development (World Bank)
ICAO International Civil Aviation Organization (See U.N.)
ICES International Council for the Exploration of the Sea
ICJ International Court of Justice
ICNT Informal Composite Negotiating Text
ICSPRO Inter-Secretariat Committee on Scientific Programmes Relating to Oceanography (See U.N.)
ICSU International Council of Scientific Unions
IDOE International Decade of Ocean Exploration (See U.N., IOC)
IGOSS Integrated Global Ocean Station System (See U.N., IOC)
IHO International Hydrographic Organization
ILO International Labour Organization (See U.N.)
IMCO Inter-governmental Maritime Consultative Organization (See U.N.)
IOC Inter Governmental Oceanographic Commission (See U.N.)
IODE International Oceanographic Data Exchange (See U.N., IOC)
IOFC Indian Ocean Fishery Commission (See U.N., FAO)
IPFC Indo-Pacific Fisheries Council (See U.N., FAO)
ITSU International Tsunami Warning System (See U.N., IOC)
IWC International Whaling Commission

LEPOR Long-term Expanded Programme of Oceanic Exploration (See U.N., IOC)
LOS Law of the Sea

MARAD Maritime Administration (See U.S. Government, Commerce Dept.)
MNC multi-national corporation
msy maximum sustainable yield
MUST Manned Undersea Science and Technology Office (See U.S. Government, Commerce Dept.)

NAS National Academy of Sciences (See U.S. Government)
NBS National Bureau of Standards (See U.S. Government, Commerce Dept.)
NGO non-governmental organization
NIEO New International Economic Order
NMFS National Marine Fisheries Service (See U.S. Government, Commerce Dept.)
NOAA National Oceanic and Atmospheric Administration (See U.S. Government, Commerce Dept.)
NOS National Ocean Survey (See U.S. Government, Commerce Dept.)
NSC National Security Council (See U.S. Government)
NSF National Science Foundation (See U.S. Government)

OAS	Organization of American States
OAU	Organization of African Unity
OCS	outer continental shelf
ODAS	Oceanographic Data Acquisition System (See U.N., IOC)
OECD	Organization for Economic Cooperation and Development
OES	Oceans and International Environmental and Scientific Affairs, Office of (See U.S. Government, State Dept.)
OMA	Ocean Mining Administration (See U.S. Government, Dept. of the Interior)
OPEC	Organization of Petroleum Exporting Countries
OSHA	Occupational Safety and Health Administration (See U.S. Government, Labor Dept.)
osy	optimum sustainable yield
OTEC	Ocean thermal energy conversion
PCB	Polychlorinated biphenyl
RSNT	Revised Single Negotiating Text
SCOR	Scientific Committee on Oceanic Research
SNT	Single Negotiating Text
TAC	Total allowable catch
TEMA	Training, Education and Mutual Assistance (See U.N., IOC)
UN	United Nations
UNA	United Nations Association
UNCLOS	United Nations Conference on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
UNITAR	United Nations Institute for Training and Research
USCG	United States Coast Guard (See U.S. Government, Dept. of Transportation)
USGS	United States Geological Survey (See U.S. Government, Dept. of the Interior)
WECAFC	Western Central Atlantic Fishery Commission (See U.N., FAO)
WHO	World Health Organization
WMO	World Meteorological Organization
WWW	World Weather Watch (See U.N., WMO)

abyssal	of or pertaining to the great depths of the ocean; the ocean floor as distinguished from the continental margin
adjustment assistance	funds to help nations re-orient domestic production taking into account changed market conditions
agglomeration	uniting of substances of fine size to form coarse particles or pellets
algin	chemical extracted from kelp seaweed used as a thickening, emulsifying, stabilizing agent in industry
alluvial	composed of sediments deposited by flowing water, whether in river beds, flood plains or deltas
anadromous	(salmon) fish species which spawn in inland waters but spend most of their life at sea
anti-monopoly	in deep seabed mining, a limit on the number of mine sites any one country or company could develop in the international seabed area
appropriate technology (see intermediate technology)	technology which makes best use of local skills, conditions and resources; terminology applied particularly to developing country needs
aquaculture	the farming or cultivating of living organisms in a water environment, whether fish or plants
archipelago	a sea containing a large group of islands; in the Law of the Sea: a nation made up of a "group of islands, including parts of islands, interconnecting waters and other natural features which are so closely interrelated that such islands, waters and other natural features form an intrinsic geographical, economic and political entity or which historically have been regarded as such." (Art. 46, ICNT)
Authority, International Seabed	The proposed agency which will govern seabed mining in the international seabed area beyond national jurisdiction. This agency will be created by the Law of the Sea Conference; will either contract for mining and/or mine through its own operating arm, the Enterprise; will set general policies for mining in its plenary Assembly; and will take operational decision in its limited member Council. It will have a Secretariat staff and may distribute funds for international community purposes derived from seabed mining.

ballast	any heavy material placed in the hold of a ship to enhance stability
banking system	under this system, in deep seabed mining, when a contractor wishes to contract to mine with the International Authority, the contractor proposes two mine sites of equal commercial value from which the Authority selects one to be held or "banked" for later exploitation by the Enterprise or developing nations, while the contractor is granted mining rights in the other area
baseline	the line established along the shore of a nation from which the territorial sea and all other zones of national jurisdiction are measured
biogenesis	the generation of living organisms from other living organisms, as opposed to generation from non-living matter
by-catch	(See incidental catch)
catadromous	(eels) fish species which spawn in ocean waters but spend most of their life cycle in inland waters
chromatographic	separation of complex mixtures through a medium which selectively absorbs materials
closed area	an area where fishing is prohibited for purposes of conservation
closed season	a time period during which fishing is prohibited for purposes of conservation
coastal species	(menhaden) fish species which remain near the shore
coastal zone	the area where the oceans (or other bodies of water) and the land interact
consent regime	for marine scientific research, the legal requirement that the researching state obtain permission from the coastal nation if it plans to conduct research in the economic zone area or on the continental shelf of the coastal nation
contiguous zone	a zone of 12 or 24 miles within which the coastal nation may exercise jurisdiction over fish, custom, immigration, fiscal or sanitary matters.

continental margin (see diagram on page III-6)	the geological prolongation of the continental land mass, composed of: shelf - shallow portion of the margin usually cut off at the 200 meter depth mark slope - beyond the shelf, the slope is where a steep decline occurs rise - at the bottom of the slope the rise is that portion of the margin where sediments have accumulated and spread out to merge with the abyssal deep ocean floor
convention	treaty
conventional	non-nuclear (military)
customary international law	laws developed from practice by many nations which come to be generally accepted by the majority of nations
DDT	insecticide; man-made organic compound not produced in nature, so that the ecosystem has not evolved mechanisms to recycle it as adequately as it does natural products
deadweight tons	(DWT) the unrelieved weight of a motionless mass, in this case used to refer to the weight of cargo, stores, fuel, equipment, passengers and crew carried aboard a ship (tanker)
de-salinization	extraction of salts and other chemicals from sea water
diatom	single cell marine plant
distant-water fishing nation	a nation whose fleets roam far from home to catch fish
drydock	to place a ship in a large floating or stationary dock in the form of a basin from which water can be emptied; used for maintaining, repairing and altering a ship below the water line

dynamically-positioned	an object which maintains its position in space by means of some form of energy, i.e., motors, etc.
economic zone	proposed 200-mile zone of coastal nation resource jurisdiction
ecosystem	the habitat, species living therein, and interactions among species and their habitat
Enterprise	the operating mining arm of the proposed Authority
enclosed sea	i.e., the Mediterranean
environmental impact statement	a statement which elaborates a particular activity's effects on the environment
equitable geographic representation	of the five world regions, Latin America, Africa, Eastern Europe, Asia and Western Europe and Others, each group of countries represents a certain percentage of world nations and would be represented accordingly as a percentage of the total number in question
estuary	an arm of the sea that extends inland to meet the mouth of a river
ethanol	an alcohol
exclusive economic zone	see economic zone
exploitation	development or utilization of resources; no negative connotations
first generation mine site	those sites able to be mined with the technology available by the time a significant number of projects are operating; i.e., first generation mining technology
flag state	nation under whose flag a ship is registered which therefore exercises regulatory jurisdiction over the ship
food chain (see diagram on page III-8)	interactions among organisms which produce food from inorganic matter (nutrients) and the sun's energy through photosynthesis, up through plant-eating (herbivores), meat-eating (carnivores) and organisms which eat both, through the life cycle to death and then decomposition into nutrients

full utilization	obligation of the coastal nation to permit foreign fishermen to harvest that portion of the annual harvest of fishery resources under its jurisdiction which coastal fishermen do not recover
geographically disadvantaged	applied to nations with short coastlines, narrow continental shelves or 200-mile resource zones cut off by nearby neighbors' zones (such as in the Caribbean Sea)
governing international fishery agreements	agreements in principle signed between the U.S. and foreign governments which recognize U.S. jurisdiction and regulatory powers over fisheries in the 200-mile fish zone, and confirm that the U.S. will make the surplus available to foreign governments
Group of 77	developing nations group, now over 100 members
habitat	the area or type of environment in which an organism or biological population normally lives or occurs
hectare	metric unit of area equal to app. 2.5 acres
highly migratory fish	(tuna) fish species which range over wide areas of the oceans
high seas	seas beyond national jurisdiction; high seas rights specifically include the freedoms of navigation, overflight, laying of submarine cables and pipelines and fishing, as defined in the 1958 Geneva Convention on the High Seas; any nation may exercise these rights as long as it does not interfere with others' exercise of the same rights
human pressure barrier	practical limit for a human diving free of a pressurized suit or a special environment capsule to reach the ocean depths
hydraulic lift	a method of mining that relies on upward flow of water to carry material to the surface (works like a vacuum)
hydrologic cycle	evaporation of seawater into vapor form which is then carried over land areas where it condenses into rain and is eventually returned to the sea through river runoff (or directly into the ocean from the coast)

hydrological	of water
incidental catch	(by-catch) fish species recovered which are not those sought by the fishermen but are mixed with those the fishermen are after
indigenous	native
informal composite negotiating text (ICNT)	texts which serve as the basis of discussion in the Law of the Sea Conference; produced July, 1977
innocent passage	the legal term for the type of passage permitted in the territorial sea: "Passage means navigation through the territorial sea for the purpose either of traversing that sea without entering internal waters, or of proceeding to internal waters, or of making for the high seas from internal waters. Passage includes stopping and anchoring, but only in so far as the same are incidental to ordinary navigation or are rendered necessary by <u>force majeure</u> or by distress. Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal state." 1958 Geneva Convention on the Territorial Sea. Innocent Passage does not include the right of overflight or submerged transit.
intermediate technology	technology which is not greatly machine dependent and thus does not make human labor obsolete but rather provides employment; appropriate for countries with large unemployed populations (See appropriate technology)
International Authority	See Authority
International Seabed Authority	See Authority
intrusive rock	volcanic rock forced into another layer while still molten
isobath	lines drawn connecting points of equal depth; underwater contour lines
kepone	chemical pesticide believed to cause cancer
kilocalorie	kilogram calorie; the unit of heat equal to the amount of heat required to raise the temperature of 1 kilogram of water by 1 degree Centigrade at 1 atmospheric pressure

kilogram	metric unit of mass equal to 2.2 pounds
kilometer	metric unit of length equal to .6 miles
krill	small shrimp-like crustacean found in the Southern Ocean; fed upon by whales and birds
land-locked	nation surrounded completely by land; no borders on the oceans
littoral	of or existing on a shore
lower 48	U.S. states on the continental mainland, excluding Alaska
machinery, international	organization or agency which puts laws into effect (See Authority)
manganese nodule	burnt potato-looking agglomeration of minerals
mariculture	the cultivation in the oceans of living organisms, whether fish or plant
maximum sustainable yield	the amount of fish which can be taken on a sustained basis without reducing the reproductive capacity of the species or affecting inter-relationships among species which support each other
metalliferous	containing metal
meter	metric unit of length equal to approximately 39 inches
methanol	an odorless, colorless, flammable gas
metropolitan power	nation administering or occupying a territory
moor	to secure or make fast by means of cables, anchors, etc.
multinational consortia	business arrangement made between several companies of several different nations
nautical mile	equal to 6,076 feet (mile is 5,280 feet)
new international economic order	re-ordering of world economic system desired by developing nations so that they can participate with equal voice and power in decisions affecting them and gain a more equitable share of the world's wealth

nodule	See manganese nodule
oceanography	the exploration and scientific study of the ocean and its phenomena
ocean thermal energy conversion	energy generated by harnessing temperature differentials in the oceans
ooze	a scientific term meaning soft, thick mud
outer continental shelf	beyond three miles in U.S. law; states of the union manage the continental shelf within three miles of shore
optimum sustainable yield	a modification of the maximum sustainable yield concept which takes into account certain social and economic factors such as dependency of local coastal population on fishing as a means of income and food supply and employment possibilities in the fishing industry
overflight	the right of an airplane to fly over territory, whether land or ocean space
oxide	(mineral) combination of an element and oxygen
Pangaea	the name for the original supercontinent from which today's continents split apart and drifted
parallel system	a type of dual mining system of exploitation of deep seabed minerals where the mining arm of the International Authority, the Enterprise, and private contractors both mine under the same basic conditions
photosynthesis	the process by which cells in green plants convert light to chemical energy and synthesize organic compounds from inorganic compounds
phytoplankton	one-celled marine plants
placer deposit	a glacial or alluvial deposit of sand or gravel containing eroded particles of valuable minerals
plankton	microscopic marine organisms which float freely
plenary	representation of full membership
polychlorinated biphenyls	(PCBs) a toxic chemical; artificial organic compound not produced in nature so that the ecosystem has not evolved mechanisms to recycle it as effectively as natural compounds

pneumatic lift	a mining system based on an air lift; run by using compressed air
port state	the state whose port a ship enters
preferential access	priority access over other nations, i.e., land-locked access to coastal state fishery resources
quota	limiting the amount of fish which can be recovered, for purposes of conservation
regime	set of laws
revised single negotiating text (RSNT)	the texts which serve as a basis of discussion in the U.N. law of the sea negotiations produced at spring, 1976 session
riparian	bordering a river
sea water	gases and inorganic salts which make up the 3.5% seawater solution; table salt (sodium chloride) accounts for 85% of the dissolved solids in seawater
semi-enclosed sea	i.e., the Caribbean
site specific	a mining operation where the technology is geared to a particular site because of bottom formation, dispersion of nodules, etc.; transferring the equipment to another site would probably require some modifications to make it operable
sovereignty	complete independence and self-government; supremacy of authority or rule
"special procedures"	in the LOS texts on dispute settlement, these are arbitration panels of five members appointed by agreement between the parties to a dispute and selected from a list of experts
stock (of fish)	a school of a species
strait	a narrow passage of water joining two larger bodies of water
strategic	essential to the effective conduct of war

sui generis	literally, growing out of itself; that is, a unique entity
sweep efficiency	the navigational accuracy of the mining dredge head which leads to overlaps or gaps in the area covered
system of exploitation	who mines, under what rules
tactical	techniques used to obtain objectives defined by strategy (See strategic)
tectonic plates	geology; structural formation of the earth's crust
territorial sea	a 3-mile wide internationally accepted zone of territorial sovereignty for coastal nations through which the only recognized international right is that of innocent passage; conceived of as a zone which helps guarantee territorial security; Law of the Sea Conference will broaden it to 12 miles
Third World	developing nations in Asia, Africa and Latin America
unilateral	an action taken by one or more states not binding on others and not recognized by them
unimpeded transit passage	the new concept developed by the Law of the Sea Conference for passage through international straits. It does include the right of overflight and of submerged passage (See innocent passage)
upwelling (see diagram on page III-8)	the rising of cold, nutrient-rich waters from the depths of the ocean caused when interactions between prevailing winds, currents and the effects of the earth's rotation cause warm surface waters to be blown away and replaced by waters from the depths
viscosity	the degree to which a fluid resists flow under an applied force
water column	the water covering the sea floor up to the water surface

REFERENCES

GENERAL

Borgese, Elisabeth Mann. Drama of the Oceans. H.N. Abrams. ($25.00)

Borgese, Elisabeth Mann and David Krieger. The Tides of Change. Mason/Charter 1975.

Borgese, Elisabeth Mann. Pacem in Maribus. ($10.00). Dodd, Mead & Co. 1972.

"A Constitution for the Sea", Department of State, Washington, D.C. 20520.

Cousteau, Jacques. Ocean World of Jacques Cousteau. Abram Pub. Co. 1974-76.
Vol. 3 "Quest for Food"
Vol. 17 "Riches of the Sea: Harvesting and Farming the Sea, Minerals and Oil"
Vol. 19 "Sea in Danger" a 20-volume set @ $7.95 a volume

Critchlow, Keith. Into the Hidden Environment: The Oceans. Viking Press, 1973. ($10.95)

Friedman, Wolfgang. The Future of the Oceans. George Brazillar Pub. 1971 ($2.45)

Heezen, Bruce C. and Charles D. Hollister. The Face of the Deep. Oxford University Press 1971 ($29.95)

Kimball, Lee. "The Law of the Sea Conference: A Major Test of International Cooperation." Overseas Development Council. 1717 Mass. Ave., N.W. Washington, D.C. 20036.

Menard, H. William and Jane L. Schreiber, eds. Oceans: Our Continuing Frontier. Courses by Newspaper. Study Guide by Helen S. Hawkins. Source Book by Mary Hellman. 1976.

"A New Regime for the Oceans." Trilateral Commission. 345 East 46th Street, New York, New York 10017. December, 1975.

Scientific American. "The Ocean" September, 1969. (General and Technical)

Swing, John Temple. "Who Will Own the Oceans?" Foreign Affairs. Spring (April) 1976.

Weiss, Mildred. "The Lawless Depths". Agenda for Action, 1974. Overseas Development Council, 1717 Mass. Ave., N.W. Washington, D.C. 20036.

OCEAN ECO-SYSTEM & RESOURCES

Branning, Timothy G. "Giant Kelp: Its Comeback Against Urchins, Sewage". Smithsonian Magazine. September, 1976.

Business Week. "Technology: Tapping the Lode on the Ocean Floor". October 19, 1974. (deep seabed mining)

Mathews, Samuel W. "This Changing Earth". National Geographic Magazine. January, 1973. (tectonic plates)

Ocean Manganese Nodules. Senate Interior Committee Print. February, 1976. Second Edition.

Oil Transportation by Tankers: An Analysis of Marine Pollution and Safety Measures. Congress Office of Technology Assessment. July, 1975.

Pirie, R. Gordon. Oceanography: Contemporary Readings in Ocean Sciences. 1973

Scientific American Readings. "Continents Adrift". Intro. by J. Tuzo Wilson. 1972

Sisselman, Robert, ed. "Ocean Miners Take Soundings on Legal Problems, Development Alternatives". Engineering and Mining Journal. April, 1975.

Spilhaus, Dr. Athelstan. "New Look in Maps Brings Out Patterns of Plate Tectonics". Smithsonian Magazine. August, 1976.

Tait, R.V. and R.S. DeSAnto. Elements of Marine Ecology. 1975.

Ward, Ritchie. Into the Ocean World. 1974.

Williams, Jerome, John J. Higginson, John D. Rohrbough. Sea and Air: The Marine Environment. Naval Institute Press. Second edition. 1973.

SATELLITES

Darden, Lloyd. The Earth in the Looking Glass. 1974.

MARINE SCIENTIFIC RESEARCH

Deacon, Margaret. Scientist and the Sea: 1650-1900. 1971.

National Academy of Sciences. U.S. Marine Scientific Research Assistance to Foreign States: Proceedings of Conference. 1975. Second edition.

POLITICAL/LEGAL

Dupuy, Rene-Jean. The Law of the Sea: Current Problems. 1974

Frank, Richard. New York Times Magazine, May 18, 1975.

Larson, David L., supervising ed. Major Issues of the Law of the Sea. by Campbell, D. III, Richard W. Pabst, Johathan A. Walz. University of New Hampshire. 1976.

Ogley, Roderick. Whose Common Heritage: Creating a Law for the Seabed. 1975. Frances Pinter Pub. Ltd. 161 West End Lane, London NW6 2LG.

Wenk, Edward Jr. The Politics of the Ocean. 1972

U.S. GOVERNMENT

Federal Ocean Program. The Annual Report of the President to the Congress on the Nation's efforts to Comprehend, Conserve, and Use the Sea. April 1975.

ENERGY FROM THE OCEANS

Gerard, R.D. and O.A. Roels. "Deep Ocean Water as a Resource" Marine Technology Society Journal. Vol. 4 No. 5. Sept-Oct., 1970, pp. 69-79.

Othmer, D.F. and A.R. Oswald. "Power, Fresh Water and Food from Cold Deep Sea Water" Science Magazine. Vol. 182, No. 4108, 12 Oct. 1973, pp. 121-125.

Richards, A.F. "Extracting Energy from the Oceans: A Review" The Marine Technology Society Journal. Vol. 10, No. 2. Feb-March, 1976, pp. 5-24.

CONTINENTAL MARGIN

Hedberg, Hollis D. "Ocean Boundaries and Petroleum Resources" Science. Vol. 191, 12 March 1976, pp. 1009-1018.

Hedberg, Hollis D. "Ocean Boundaries for the Law of the Sea." Marine Technology Society Journal. Vol. 10, No. 5, June 1976.

FISH - OCEAN

Eckholm, Erik P. Losing Ground: Environmental Stress and World Food Prospects. World Watch Institute, W.W. Norton Company, Inc., New York, 1976.

Fishery Development for the Future, FAO Department of Fisheries, Document No. PI/F2865/E/10.74/1/5000.

Kent, George. "Dominance in Fishing," Journal of Peace Research, No. 1, Vol. XIII, 1976.

Kimball, Lee. "Rational Management of Fishery Resources: An Issue in the Law of the Sea," available from the Ocean Education Project, 245 2nd Street, N.E., Washington, D.C. 20002.

Prospects for Fisheries Development Assistance, International Center for Marine Resource Development, University of Rhode Island, Marine Technical Report Series 19, Kingston, 1974.

"The Resources of the Oceans -- Protecting and Developing Them," Development Issue Paper 8, United Nations Development Programme and Food and Agriculture Organization.
Series: Global - I: Changing Factors in World Development.
Contact Donald J. Casey, Division of Information: (212) 754-1234, ext. 3852.

Warner, William. "The Politics of Fish," The Atlantic, August, 1977. ("A firsthand view of the international fishing community as seen from the decks of a West German factory trawler.")

Marx, Wesley. "Oceans are Vastly Overrated as a Source of Food and Fuel," Smithsonian Magazine, 5:26-35, June, 1974.

Resources for the Future, Inc., 1755 Mass. Ave., N.W., Washington, D.C. 20036. Several detailed studies on overfishing, regional fishery problems and prospects, and global management. Authors include Francis Christy, Edward Miles, Mr. Crutchfield, etc.

Gulland, ed., The Fish Resources of the Ocean.

TECHNICAL

An Assessment of the Impact of Proposed Changes in the Law of the Sea On Regional Fishery Commissions, On FAO Technical Assistance Programmes In Fisheries and on the FAO Committee on Fisheries and Department of Fisheries, FAO: Committee on Fisheries-Subcommittee on Development of Cooperation with International Organizations concerned with Fisheries, COFI: C/4/76/INF. 3, February, 1976.

A Summary of the Discussions of the Expert Consultation on the Future Role of FAO in Fisheries, of COFI and Regional Fishery Bodies, FAO: Committee on Fisheries-Subcommittee on the Development of Cooperation with International Organizations concerned with Fisheries, COFI: C/4/76/4, February, 1976.

Liston, John and Lynwood Smith. "Fishing and the Fishing Industry: An Account with Comments on Overseas Technology Transfer," Ocean Development and International Law, Vol. 2, No. 4 (Winter, 1974).

LAW OF THE SEA

Borgese, Elisabeth Mann. "A Ten Year Struggle for the Law of the Sea," Center Magazine, May-June, 1977.

Charney, Jonathan. "Law of the Sea: Breaking the Deadlock," Foreign Affairs, April, 1977.

Claiborne. "High-Stakes Seabed Fight - Lobbyist Is Everywhere," The Washington Post, Sunday, August 14, 1977.

Discovery. United Methodist Law of the Sea Project, 100 Maryland Avenue, N.E., Washington, D.C. 20002.

"Manganese Nodule Mining: Where Are We In 1976?" available from the Ocean Education Project, 245 2nd Street, N.E., Washington, D.C. 20002.

NEPTUNE. Ocean Education Project, 245 2nd Street, N.E., Washington, D.C. 20002.

"Ocean Manganese Nodules," Congressional Research Service, 94th Congress, second session. Second edition of Committee Print of the Senate Interior and Insular Affairs Committee. 65-675 O.

Raymond, Richard C. "Seabed Minerals and the U.S. Economy: A Second Look," inserted in the Congressional Record-Extensions of Remarks, February 10, 1977. Reprinted from the Journal of the Marine Technology Society. June, 1976, Volume 10, No. 5.

Sea Breezes. U.S. Committee for the Oceans, 245 2nd Street, N.E., Washington, D.C. 20002.

SOUNDINGS. Ocean Education Project, 245 2nd Street, N.E., Washington, D.C. 20002.

Third United Nations Conference on Law of Sea To Hold Sixth Session In New York, Starting 23 May. A United Nations Office of Public Information Press Release (backgrounder), SEA/255, May 19, 1977.

Unclassified U.S. Delegation Report on the Law of the Sea Conference, available from the U.S. Law of Sea Office, Department of State, Washington, D.C. 20520.

Wertenbaker, William. "Mining the Wealth of the Ocean Deep," New York Times Sunday Magazine, July 17, 1977.